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ABSTRACT

A project developed a solar-related vocational training curriculum for use in the general technical trades training curriculum. Forty-seven firms comprising Washington State's "solar industry" were surveyed to identify existing and emerging solar-related occupations and prerequisites for entry. Results indicated that solar technologies most likely to achieve the greatest market penetration were domestic hot water systems, swimming pool heaters, and passive/passive hybrid systems. Job requirements of entry level solar workers were a combination of skills from carpentry, sheet metal, plumbing, and pipefitting. A formal task analysis for four solar-related occupations (carpentry, sheet metal, electrician, and plumbing/pipefitting) as they pertain to four generic solar technologies focused on tasks involved in installation and maintenance of solar systems. A "Solar Mechanics Vocational Training Curriculum," consisting of course goals, course descriptions, prime and performance objectives, and a course outline, was prepared. Individuals entering the open entry, open exit program are assumed to possess entry-level skills in carpentry, plumbing and pipefitting, or electrical maintenance. (Appendixes, amounting to over one-half of the report, include a report describing solar technologies appropriate to the Puget Sound Region, solar occupations survey and results, literature review, tasks analysis, preliminary curriuclum, and manpower projection.) (YLB)

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ED187900

FINAL REPORT

Project No. 78-AFK(138)NP

DEVELOPMENT OF A SOLAR RELATED VOCATIONAL TRAINING CURRICULUM

Research Project in Vocational Education
Conducted Under Public Law 90-576

The project reported herein was performed pursuant to a grant from the Research Coordinating Unit of the Washington State Commission for Vocational Education. Contractors undertaking such projects are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Commission for Vocational Education position or policy.

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SUMMARY

A. The duration of the project was from April 15, 1978 to April 30, 1979. The project was subsequently extended to May 31, 1979.

B. The overall goal of the project was to develop a solar-related vocational training curriculum for use in the general technical trades training curriculum.

The objectives of this project were to:

1. Establish a Technical Advisory Committee to provide "state-of-the-arts" information on solar-related industries and programs and to assist in project evaluation,
2. Identify existing and emerging solar-related occupations, including prerequisites for entry and requirements peculiar to the Northwest,
3. Identify existing and potential labor markets for solar-related occupations,
4. Develop a task analysis for occupations having a strong labor demand; and,
5. Develop a vocational training curriculum that will adequately prepare students for employment in solar-related occupations. The curriculum is to include: a) course goals, b) course descriptions, c) prime objectives which are a statement of the principal skills an enrollee will have after completing the course, d) course requirements and e) performance objectives which state specifically what an individual will be able to demonstrate after having

acquired specific skills and knowledge.

C. Procedures followed were:

1. A Technical Advisory Committee was established to provide "state-of-the-arts" information on solar related industries and programs, 2) assistance in monitoring and assessment and 3) assistance in the evaluation of the project.
2. The project's technical consultants, Ecotope Group, conducted an assessment of the solar technologies appropriate for Washington State.
3. The project's staff conducted a survey of solar technology manufacturers, distributors and others considered to possess "informed opinion" on the current and near term (next 18 months) demand for solar workers and the job requirements of these workers.
4. The project's staff conducted an extensive review of the literature to assess a) the expected demand for solar energy systems, b) the projected manpower requirements created by the deployment of solar technologies and c) the general task performed in the installation of a generalized solar energy system.
5. The project's staff, in consultation with the Technical Advisory Committee, selected three solar technologies for which a detailed analysis of labor needs was conducted.
6. A market penetration analysis was prepared by the project's technical consultants for each of the three selected solar technologies.

7. The results of the market penetration analysis were used to derive estimates of the labor market demand for selected solar-related occupations.

8. The market penetration analysis and estimates of manpower needs were reviewed by the project's Technical Advisory Committee, and accepted.

9. The project staff prepared a formal task analysis for selected solar-related occupations.

10. The formal task analysis was reviewed by the TAC.

11. The task analysis was revised by project staff, reviewed again by the TAC, and accepted.

12. Course description, goals, prime and performance objectives and course content outline were drafted by project staff and submitted to the TAC for review and evaluation.

13. The course description, goals, prime and performance objectives and course content outline were submitted to Seattle/OIC instructional personnel for evaluation.

14. Revisions were made in the course description, goals, prime and performance objectives and course content outline based on the TAC and Seattle/OIC instructional staff comments.

15. The revised course description, goals, prime and performance objectives and course content outline were reviewed by the TAC, and accepted.

D. Results/Accomplishments

1. A fourteen member Solar Technical Advisory Committee was

established. This committee held six meetings and provided advice to the project staff and reviewed the project's "working papers."

2. A survey of individuals and firms who presently comprise Washington State's "solar industry" was carried out to identify existing and emerging solar-related occupations, including prerequisites for entry. More than one fourth of the firms identified responded to the survey.
3. The existing level of demand for solar-related occupations was established and projections were made for the potential future demand for these occupations in the Seattle/King County area for the years 1980-1986.
4. A formal task analysis was prepared for four solar-related occupations (carpentry, sheet metal, electrician and plumbing/pipefitting) as they pertain to four generic Solar technologies.
5. A "Solar Mechanics Vocational Training Curriculum" consisting of course goals, course description, prime objectives, course requirements, performance objectives and a course content outline was prepared.

E. The principal objective of this project was to develop a solar-related vocational training curriculum. This objective was achieved. The projects other objectives, relating to the development of specific information needed for curriculum development were also met.

F. The major conclusions and recommendations of this project are:

1. Those solar technologies most likely to achieve the greatest

market penetration in Washington are: domestic hot water systems, swimming pool heaters and passive/passive hybrid systems.

2. The occupations most closely associated with these technologies are carpentry, plumbing, electrical maintenance and sheet metal.

3. The job requirements of an entry level solar worker ("solar mechanic") appear to consist of a combination of skills from carpentry, sheet metal, plumbing and pipefitting.

4. In the near term (next 18 months) the demand for solar-related occupations does not justify training individuals for work exclusively in the solar field, but requires only that existing curriculums be augmented to include solar training relevant to traditional trades e.g. "solar carpentry", "solar plumbing."

NARRATIVE OF REPORT

A. Problem area toward which the project was directed: The era of cheap and abundant fossil fuels has ended. As their prices rise and their availability declines, the existing economic structure will change. Lower cost, more readily available resources, in both energy and non-energy forms will be substituted for high priced fossil fuels and electricity. As a result of the changing economic structure, existing occupations will be modified and new occupations created, particularly in the energy field. With these changes comes the need for job training and retraining.

Of the alternatives available for meeting our energy needs, those technologies which utilized solar energy appear to hold the most promise and are currently receiving the most support. In a recent report, the President's Council on Environmental Quality estimated that under conditions of accelerated development and with a serious effort to conserve energy, solar technology could meet a quarter of the U.S. energy needs the year 2000.[1] Such a transition is expected to result in creating more than 25.3 million labor years of employment.[2]

[1] Council on Environmental Quality Solar Energy: Progress and Promise. U.S. Government Printing Office; Washington, D.C., April, 1978)

[2] Domestic Policy Review Integration Group. "Status Report on Solar Energy Domestic Policy Review. (Department of Energy, August 25, 1978). For a more detailed review of the anticipated employment impacts of solar/conservation futures see Appendix VI.

Taken together, the changing energy supply picture and its concommitant effects on labor requirements have created a tremendous need for curriculum revision and development in the area of energy related vocational training. As was indicated in this project's original proposal, only modest efforts have been directed at addressing this need.[3] This project sought to fulfill a portion of this need. It attempted to identify emerging solar-related occupations and develop a curriculum to train individuals for those occupations. In particular, it focused on entry-level solar-related occupations for which a training curriculum could be developed which would dovetail with existing technical trades training in the areas of carpentry, plumbing and pipefitting.

B. Goals and Objectives of Project

The overall goal of this project was to develop a solar-related vocational training curriculum for use in the general technical trades training curricula. Specifically, its objectives were to:

1. Establish a Technical Advisory Committee to provide "state-of-the-arts" information on solar-related industries and programs and to assist in project evaluation,
2. Identify existing and emerging solar-related occupations, including prerequisites for entry and requirements peculiar to the Northwest,
3. Identify existing and potential labor markets for solar-related occupations,

[3]Seattle/OIC. "Development of a Solar-Related Vocational Training Curriculum" Proposal to the Commission for Vocational Education. April, 1978. See pages 4-5.

4. Develop a task analyses for occupations which exhibit a strong labor demand; and,

5. Develop a vocational training curriculum that will adequately prepare students for employment in solar-related occupations. This curriculum is to include: a) course goals, b) course description, c) prime objectives which are a statement of the principal skills an enrollee will have after completing the course, d) course requirements and e) performance objectives which state specifically what an individual will be able to demonstrate after having acquired specific skills and knowledge.

C. Project Design

The project design followed in this project consisted of three broad phases; the first phase was to identify the solar technologies and their attendant labor requirements appropriate for use in Washington State. Once these technologies were identified, a labor market analysis was conducted to determine the existing and potential demand for solar-related occupations. The results of the second phase of the project were used to identify the occupations for which the curriculum was developed during phase three. This entire process was monitored by a Technical Advisory Committee consisting of individuals with an interest and/or expertise in alternative energy sources or vocational training.

The specific procedures utilized as part of this project design were as follows:

1. Establishment of a Technical Advisory Committee (TAC)

The project staff, in consultation with the project's technical consultants, identified individuals who could represent education, government, business, the trades, utilities, the community at large and others with scientific and technical expertise. A list of potential members was then prepared for review by Seattle/OIC's Executive Director. Following his review, letters of invitation were sent to the individuals selected. (See Appendix I). Project staff followed up these letters with a phone call to answer potential members questions regarding the project and their role in the TAC. All individuals invited to serve on the TAC accepted the invitation (See Appendix II).

2. Identification of existing and emerging solar-related occupations applicable to the Pacific Northwest - In order to accomplish this project component, two tasks were carried out. First, the project's technical consultants conducted an assessment of the solar technologies most appropriate for Washington State. This process began with the preparation of a list of candidate technologies by project staff and technical consultants. A working paper (See Appendix III) was then prepared and distributed to the TAC for review.

Concurrent with the TAC's review, the project staff undertook a survey of existing solar system manufacturers, distributors

and contractors in Washington State. The purpose of this survey was to: 1) assess the industry's opinion as to what technologies are most appropriate for use in this State 2) identify the existing level of employment in Washington's solar industry 3) ascertain the industry's estimate of the short term (next 18 months) need for trained solar workers; and, 4) identify the entry level skills, knowledge and personal qualities desirable in a solar worker (See Appendix IV).

Based on the Technical Advisory Committee's review and the results of this survey, three solar technologies were identified that are expected to achieve the greatest use in Washington during the next two to five years (See Appendix V).

3. Development of a labor market analysis for existing and emerging solar-related occupations - The development of the labor market data required the performance of two major tasks. The first task performed was a survey of existing information sources. This included an extensive review of the literature (See Appendix VI), and a survey of firms currently active in Washington who supply solar systems.

As part of the literature review, existing labor market forecasts prepared by such agencies as the Department of Labor and Employment Security were evaluated. Through this process it was discovered that, to date, no estimates of the existing labor demand, nor projections of future manpower needs have

been prepared for solar-related occupations in Washington State. Consequently, a second task was performed to develop such information.

The strategy for this second task required that a market penetration forecast be developed for the three solar technologies identified as likely to experience the greatest near term use. This study was performed by the project's technical consultants. Their forecast, after review by the TAC, was then used to derive an estimate of the manpower demand for solar-related occupations. [1](See Appendix VII and VIII).

4. Identification of possible solar-related occupations applicable to carpentry, plumbing and pipefitting training

Three modes were used to identify possible solar-related occupations.

a. A review of the literature

b. A survey of existing solar, manufacturers, distributors, and contractors; and,

c. Discussions with members of the Technical Advisory Committee and the project's technical consultants.

The results of these assessments were discussed by Seattle/OIC staff and presented to the Technical Advisory Committee. Subseqeuntly, a determination was made as regards which solar-

[1]Due to budget and data constraints these projections were developed for only a limited geographic area (Seattle/King County).

related occupations were applicable to carpentry, plumbing and pipefitting training based on their consistency with and similarity to current training in these occupations.

5. Informal task analysis of solar-related occupations - An informal analyses of the task that a person working in solar-related occupation might perform was prepared through an extensive review of the available literature (See Appendix VI). This review was augmented by a survey of solar firms active in Washington State. The results of this review were then discussed with the TAC to assess the relationship of these tasks to existing Seattle/OIC training goals and programs.

6. Selection of several occupations which have a high labor market demand for curriculum - The project staff, in consultation with the TAC technical consultants and other Seattle/OIC staff selected two occupations for curriculum development. This selection was based on the following criteria:

   a. The occupation exhibits a high labor market demand
   b. Training cuold be completed in a 20-52 week time period
   c. Training could be dovetailed with existing training and/or be used as an advanced upgrade program
   d. The occupations exhibit a high correlation with carpentry and plumbing and pipefitting training
   e. Training will be cost-effective, i.e. no extraordinary expenditures for special equipment, tools and materials

will be necessary; and

f. Course prerequisites will not include requirements other than the basic knowledge needed for carpentry and plumbing and pipefitting.

7. Formal task analysis - A formal task analysis was conducted using a combination of mechanisms. First, the project's staff and technical consultants prepared a preliminary list of tasks based on their prior experience and on an extensive review of the literature. This list was then reviewed by the TAC. Their comments were used to revise and expand the task analysis. The revised version of the task analysis was then reviwed by Seattle/OIC curriculum development staff and further changes were made based on their input. This amended version was resubmitted to the TAC who accepted its contents (See Appendix VIII).

8. Development of a solar-related training curriculum - The results of the occupational task analysis served as the primary basis for developing the solar-related training curriculum. The tasks identified in the analysis were evaluated and grouped according to specific solar technologies and occupations. Then, the skills and knowledge needed to accomplish these tasks were assessed by the project's staff and technical consultants as to their relative level of difficulty. The tasks were also assessed as to the order in which they would be performed by an entry level solar worker.

A course outline was then developed by the project's staff which integrated the results of this categorization and sequencing into specific course goals and prime and general performance objectives. This outline was reviewed by the project's technical consultants and TAC and other Seattle/OIC staff. Their comments were used to prepare a final version of the outline (See Appendix IX).

9. Evaluation of the solar-related vocational training curriculum - The evaluation of the solar-related training curriculum developed during the course of this project was carried out using both an internal and external review process. The project's Technical Advisory Committee (TAC) served as the principal external review organ. Internally, Seattle/OIC's Curriculum Coordinator evaluated the working drafts of both the task analyses and course outline for consistency and completeness as regards the existing carpentry and plumbing and pipefitting curriculums. Seattle/OIC's Management Analyst also evaluated the project's progress. His comments appear in Section E, pages 17-20.

D. Results and Accomplishments of the Project

1. A fourteen member Solar Technical Advisory Committee representing a broad spectrum of community interest and technical expertise was established. This committee held six meetings. It monitored and evaluated all of the projects working papers and provided valuable technical assistance and recommendations.

2. A survey of individuals and firms comprising Washington State's "solar industry" was carried out to identify existing and emerging solar-related occupations, including prerequisites for job entry. A total of 47 firms were contacted. More than one fourth of these firms responded to the survey. To date, the results of this survey represent the only available information on the status of Washington's Solar Industry. Its major findings were as follows:

   - Nearly one half of the firms responding were engaged in multiple functions, with design and retail distribution being the major services offered.
   - The most frequently handled solar technologies were domestic hot water systems, swimming pool heaters, active-air space heating systems and greenhouses.
   - Sheet metal workers, carpenters, plumbers and electricians were the major solar-related occupations identified as being most needed.
   - Nearly three quarters of those responding expected new occupations to evolve in the installation, maintenance or manufacture of solar systems/equipment. The large majority felt that an individual filling these positions would be capable of doing both design and installation work involving a variety of building trade skills.
   - Wages for entry level employees doing solar work range from $4.00 per hour to more than $7.50 with the average between $5.00 and $5.50. These wages are comparable to

entry-level wages in other trades.

- Salaries for "solar technicians" exhibit the same range as entry level workers, but the average wage is higher, between $5.75 and $6.00/hour.
- The demand for solar workers during the next 18 mohths is estimated to be 14 entry level ("solar mechanics") and 31 "solar technicians" (See Appendix V).

4. The cumulative mid-term (1980-1986) demand for solar-related occupations in the Seattle and King County area was estimated at between 615 and 2620 employee/years (See Appendix IX). Major factors which will influence the actual level of demand for solar workers include:
   - the cost of traditional forms of energy relative to solar technology,
   - the type and number of utility and/or governmental incentives provided;and,
   - improvements in solar technology which result in lower solar system costs.
5. A formal task analysis was prepared for four solar-related occupations (carpentry, sheet metal, electrician and plumbing/pipefitting) as they pertain to four generic solar technologies. This task analysis concentrated on the skills and knowledge needed to install and maintain equipment common to the most appropriate solar technologies for this region. It focused on those tasks involved in the installation and maintenance of solar systems which are primarily mechanical

(as opposed to primarily quantitative) and which are distinct from those already performed by entry-level carpentry, plumbing and pipefitting and electrical maintenance people (See Appendix VIII).

6. A "Solar Mechanics Vocational Training Curriculum" consisting of course goals, course description, prime and performance objectives and a course outline was prepared. This outline assumes that individuals entering the program already possess "entry level" skills in one of the following trades: carpentry, plumbing and pipefitting or electrical maintenance. It is divided into three blocks which are; a) Introduction to Energy Conservation and Solar Energy, b) Basic Solar Domestic Water Heating Installation and Servicing and c) Basic Solar Space Heating Installation and Servicing. The course is designed to be offered on an open-entry, open-exit basis. The average participant is expected to be able to complete the course in from 6-8 weeks with between 210-280 contact hours (See Appendix X).

E. Evaluation

The Seattle/OIC Department of Planning, Program Development, Research and Evaluation monitored the progress of the project to assure the completion of its objectives, in keeping track of scheduled events and analyzing problems during the course of the implementation.

This evaluation was to assess the outcomes and to relate them to project objectives. Agencies at the city, county and state levels as well as solar energy oriented industries should benefit from the research work conducted under this grant from the Commission for Vocational Education, under Part C, Public Law 90-576.

The project was aimed at identifying existing and emerging solar-related occupations including prerequisites for entry and requirements peculiar to the Northwest: solar energy industries and occupations. The project also had an objective to develop a task analysis for occupations having strong labor demand and develop a vocational training curriculum for training of students for employment in solar-related occupations.

All the objectives were fully met and meaningful research has been conducted to serve as the basis for actual implementation of such a curriculum to meet the need during the years 1980-1986.

The establishment of a Technical Advisory Committee consisting of representatives of education, government, business, the trades, utilities and individuals with scientific and technical expertise, was a milestone for the project as subsequent research proved that no such effort was put together in the State of Washington. The TAC membership provided all the required expertise and talents (Appendix II). The committee reviewed all the task analyses prepared at various stages and guided the project staff in accomplishing the objectives.

The development of a labor market analysis for existing and emerging solar-related occupations took considerable amount of research and time as no such review or projection of future manpower needs was prepared for Washington State. The study was used to project future needs of trained workers in the solar-related occupations. Budget and data constraints restricted develipment of the projections for Seattle/King County area only. This analysis will be useful for any agency related to solar energy utilization plans.

A determination was made regarding which solar-related occupations were most likely to be in demand and applicable to Seattle/OIC skill areas training presently available. These were carpentry and plumbing/pipefitting skills. A blending of specialized training with the existing instruction programs seemed to be feasible to meet the demands of the solar-related occupations. It is important to know that expansion into a new field like solar energy utilization could be supported with a few modifications in the existing training systems.

Development of a suitable curriculum, which would be cost effective and could accommodate students in carpentry and plumbing/pipefitting skill areas for additional training, was achieved by Seattle/OIC curriculum staff. A course outline was developed by the project staff, which integrated tasks to be performed by an entry level solar worker into specific goals and prime and general performance objectives.

Recommendations

The research conducted for this project is very vital in planning energy conservation and harnessing solar energy as well as to implement skill training programs to support the new occupational needs in the immediate future in Washington State. Seattle/OIC participation in this project has confirmed the need for a concerted effort by education and industry to forge ahead together in solving the energy crisis by careful planning and skillful implementation of the research findings.

F. Conclusions, implications and recommendations for the future

The major conclusions and recommendations of this project are:

1. Based on the results of a survey of existing solar industry firms, an analysis prepared by the project's technical consultants, and the informed opinion of the project's TAC, those solar technologies most likely to achieve the greatest market penetration in Washington State are: domestic hot water systems, swimming pool heaters and passive/passive hybrid systems.
2. The occupations most closely associated with these technologies are carpentry, plumbing, electrical maintenance and sheet metal.
3. The job requirements of an entry level solar worker (i.e. "solar mechanic") appear to consist of a combination of skills from carpentry, sheet metal, plumbing and pipefitting.
4. In the near term (next 18 months) the demand for solar-related occupations does not justify training individuals

to work exclusively in the solar field, but requires only that existing curriculums be augmented to include solar training relevant to traditional trades, e.g. solar carpentry, solar plumbing, etc., and finally,

5. Due to the absence of labor demand information for new and emerging energy related occupations and the dynamics of alternative technology developm ent it is recommended a project be initiated to develop such forecast on an annual basis.

APPENDICES

Seattle/Opportunities Industrialization Center

Seattle Opportunities Industrialization Center (Seattle/OIC) is a community based, non-profit vocational training and job placement organization. Its primary purpose is to counsel, train and place economically disadvantaged individuals in entry-level occupations. Our present curriculum provides training in eleven areas, including carpentry, plumbing, electrical maintenance, welding and clerical skills.

Seattle/OIC recently initiated a research project to assess the employment potential resulting from the deployment of solar energy systems. Through this project we hope to identify the type and number of job opportunities created by the use of solar energy and ultimately develop an appropriate vocational curriculum to train individuals to fill those jobs.

Seattle/OIC is interested in developing quality programs which reflect real world needs and conditions. To ensure that our solar energy related training efforts achieve this goal we are now forming an Advisory Committee to monitor the project. This committee will consist of individuals from the crafts, government, business, utilities, education and scientific/technical communities.

With the foregoing background, I would like to cordially extend an invitation to you to participate on this committee. I believe that your particular knowledge and expertise would provide valuable counsel to us in our efforts to develop a sound training program.

Tom Eckman, the Seattle/OIC staff member in charge of this project, will be contacting you within the next week to discuss this invitation and the project. If you have any questions concerning the specific function of the Advisory Committee, and your role on it, please feel free to contact him at (206) 223-2805.

Thank you for your time and consideration of this invitation. We look forward to your valuable assistance and participation in this project.

Sincerely,

James L Williams
Executive Director

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APPENDIX II

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Seattle/Opportunities Industrialization Center

A DESCRIPTION OF SOLAR TECHNOLOGIES APPROPRIATE FOR USE IN THE PUGET SOUND REGION OF WESTERN WASHINGTON

INTRODUCTION

As part of a project to "Develop a Solar-Related Vocational Training Curriculum" Seattle/OIC commissioned Ecotope Group to prepare a report describing those solar energy technologies appropriate for use in the Puget Sound Region. Initially, descriptions were prepared for four general technical categories:

1. Active Solar Systems
2. Passive Solar Systems
3. Renewable Energy Systems (indirect solar)
4. Thermal Efficiency/Energy Efficiency Technologies

Of these four categories, two were selected for in-depth market penetration analysis. These were: Active Solar Systems and Passive Solar Systems. Of the two remaining categories, Renewable Energy Systems (indirect solar) was eliminated from detailed consideration because the occupations related to the deployment of such systems was not closely tied to Seattle/OIC ongoing and proposed training program. Thermal Efficiency/Energy Efficiency Technologies was not selected for detailed analysis because considerable information already exists as regards the skills required and labor requirements of this category.

The remainder of this paper provides a general overview of five generalized solar technologies. These include: active space heating, passive space heating,, passive hybrid space heating, solar water heating and swimming pool heating.

SOLAR ACTIVE SPACE HEATING

The technology associated with active space heating is among the most established in the solar industry. It revolves around three principal components:

Flat plate collector: The flat plate collector is basically a glazed, insulated box 6" to 10" thick with 18 to 30 square feet of area facing the sun (south). It is manufactured in a variety of designs by a variety of manufacturers. It is simple, easily adapted to mass production. There are about 200 "different" collectors made in the U. S. They vary in cost between $2/square foot for simple swimming pool heaters to $20/ft^2 for high grade, special use collectors.

This paper was prepared under a project partially funded by the Washington Commission for Vocational Education. The views and conclusions contained in this document, however, do not necessarily represent those of the Commission or its staff.

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SOLAR ACTIVE SPACE HEATING, continued

Collector efficiencies are largely determined by their design configuration and operating temperature (the difference between the collector surface temperature and the outside air temperature). There are three generic configurations of flat plates:

Trickle - In this system the collector is allowed to warm and the working fluid (air, water glycol, etc.) is allowed to flow over it. In a water system, the water is pumped to the top and picks up heat as it trickles down over the entire surface. In an air system, the air flows up over the collecting surface by either convection or through the use of a blower(fan).

Water trickle systems are quite inexpensive and operate at excellent efficiencies when the water temperature being collected is in the range of 90^0. They are especially applicable for heating swimming pools for this reason. The air systems generally operate at about 140^0 to 180^0 F which makes them more appropriate for use in active air space heating systems.

Figure I depicts a typical air heating system.

Tube on Sheet - In this design, the fluid flows through tubes attached to or integral with the collector plate. This system is characterized by higher efficiencies at temperatures of about 140^0 F. Therefore, the tube on sheet designs are commonly used for heating domestic hot water. This system employs a liquid working fluid, usually water or glycol (where freezing is a problem), due to the necessity of passing the working fluid through the collector tubes. Figure II depicts a typical liquid system.

Evacuated Tube/Concentrator - This configuration is designed to yield higher temperatures at higher efficiencies than other flat plate collectors. The system is characterized by some mechanism which concentrates the energy collected such as a parabolic concentrator, a Fernell lens-type concentrator (Northrup) or a hybrid evacuated tube system (Owens-Corning). These systems can produce high temperatures and are often used for powering solar air conditioning systems (serville cycle).

Storage: The storage of the collected solar energy in the form of heat constitutes the second major component of an active solar heating system. A storage systems basic ingredients is material with a large specific heat and/or density. The use of such material allows large quantities of heat to be stored in relatively compact areas. The materials usually selected are either rocks for systems where air is the collecting medium, or water in liquid systems. In a liquid system, usually a heat exchanger is employed to transfer heat from the collecting fluid to the storage water. While this reduces the efficiencies, it also allows a freeze-proof system to operate using water rather than expensive solutions as a storage medium.

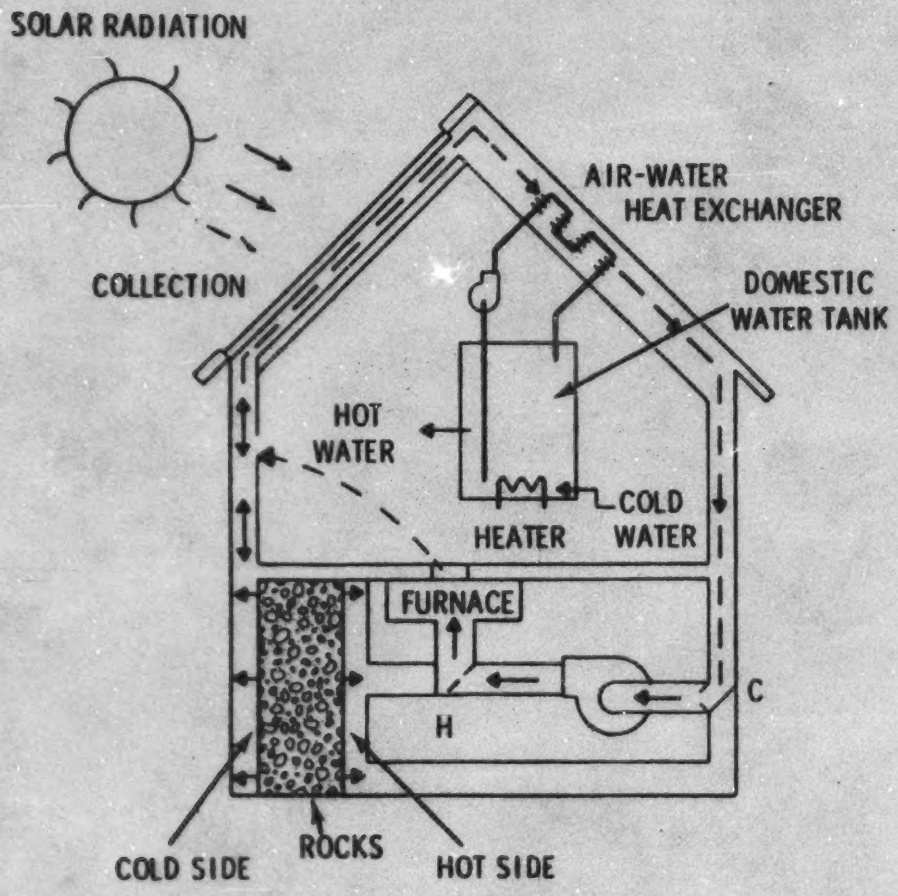

FIGURE I A Typical Air System

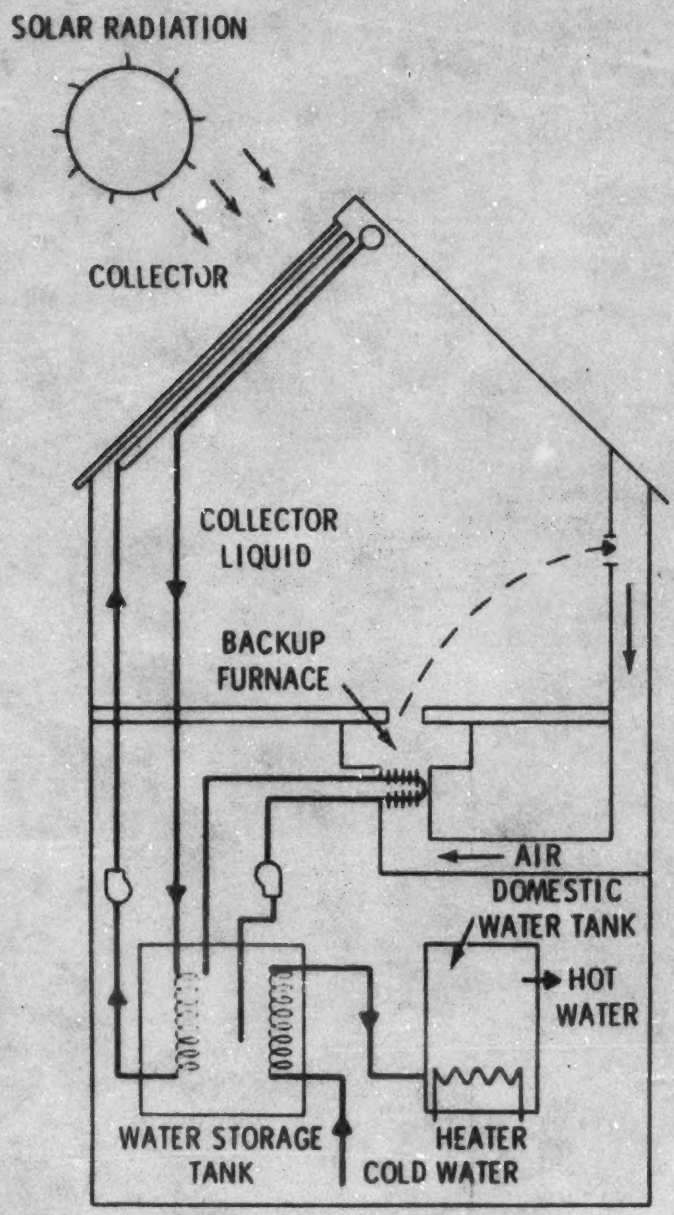

FIGURE II A Typical Liquid System

Recently, an alternative material for use in heat storage has been developed. This material, called "glauber salt" can hold more heat per unit mass because it changes phases (i.e. from a solid to a liquid)when heated at temperatures of about 90^0 F . Since pound for pound the energy required to change this material from solid at 89^0 F to liquid at 90^0 F is about 30 times that of water and 100 times that of rock, this material can store heat in a much lower volume. Where space is crucial, this results in a very small and efficient storage system. Unfortunately, the system is also somewhat more expensive.

Distribution Systems: The distribution and control systems for active solar heating systems have been refined in recent years. The central control mechanism is a differential thermostat. This is a small logic circuit which compares the temperature of the collector surface with the temperature storage and operates a pump or blower if the collector temperature is higher than storage, or if the collector has reached an adequate temperature. The remainder of the system is a series of ducts and air handlers (fans) or plumbing and pumps which move the heat collecting medium through the collector to the storage.

USE SECTORS

Active systems can be used to generate low grade (temperature)/heat for building heating and domestic hot water. In this locality (economics aside), the active system can be used for home heating, commercial space heating, domestic water heating and swimming pool heating. Solar air conditioning is also possible; however, the current state of the technology will require advances in both efficiencies and economics before any extensive application could be expected here.

MARKET DEMAND

The market for flat plate active systems is much softer here than in most other areas of the country. Several factors combined to cause the limited usage of active solar system. First, active systems are relatively expensive when compared to the present low cost of electric space heating in the region. Secondly, only a modest solar resource is available in the Northwest. Even with the region's mild climate, the limited availability of sunshine during the heating season present a severe constraint on active system use. As a result, absent very simple, very cheap systems, active solar space heating can be expected to have a market limited to those who will purchase solar systems for reasons other than economic viability.

It should be noted, however, that for domestic water heating, where flat plate technologies are better adapted, the market for these systems could be quite extensive. Indeed, solar water heaters are competitive with the"marginal cost" of energy in the present economy.

SOLAR PASSIVE SPACE HEATING

Passive solar space heating concepts are quite appropriate in the Pacific Northwest. Most passive heating systems suitable for the PNW can be divided into three basic categories: direct gain, thermal storage wall, and attached greenhouses. Sketches of these concepts are shown in Figures III a - c.

Direct Gain: The direct gain system is the simplest apporach to passive solar heating. It utilizes an expanse of south facing double glazed (i.e. two panes of glass)window combined with a large amount of thermal mass, usually a masonry floor and masonry walls with insulation on the outside. The building itself becomes a live-in solar collector. Solar radiation passes through the glass and heats the massive walls and floor, which act as combined absorbers and heat storage units. Movable insulating panels may be used to cover the windows when energy is not being collected, thus minimizing heat loss at night and during very cloudy days. See Figure III (a).

Thermal Storage Wall: The thermal storage wall concept also uses an expanse of south-facing double glazed window. However, a thermal storage wall is placed between the window and the living space. The wall is made of any heat storage material, the most common being dense concrete, brick adobe or water in containers. The wall acts as both absorber and storage unit and is usually painted a dark color to improve solar absorption. The wall absorbs solar radiation during the day and then transfers heat into the living space by radiation and convection. A modified heat storage wall concept, known as the Trombe Wall, utilizes vents at the top and bottom of the heat storage wall to allow free convection of room air over the warm outer wall and then back into the room. This provides an additional path for heat to enter the living space. See Figure III (b).

Attached Greenhouse: The third passive heating concept is actually a combination of the first two. It utilizes a greenhouse attached to the main building with a thermal storage wall between the two. Solar radiation not only provides enough excess heat in the heat storage wall to supply some of the requirements of the main building. The attached greenhouse concept has the advantage of providing not only building heat but also a place to grow food during the colder months. See Figure III (c).

USE SECTORS - Passive Systems can be used to generate low temperature heat needed for space heating in residential, commercial and industrial structures. At present the major application of passive systems are in the residential and commercial sectors.

MARKET DEMAND - Passive Systems can be integrated into new buildings as part of the architecture at very little additional cost. Thus, they are very cost-effective in new construction. Moreover, because passive systems are so simple and use standard building materials, maintenance costs are almost non-existent. Also, it is possible to combine different passive concepts in a single structure, thus allowing great flexibility in the arrangement of passive homes and buildings.

The use of passive systems in existing structures is much more difficult to accomplish. As a result, while some passive retrofit approaches such as window

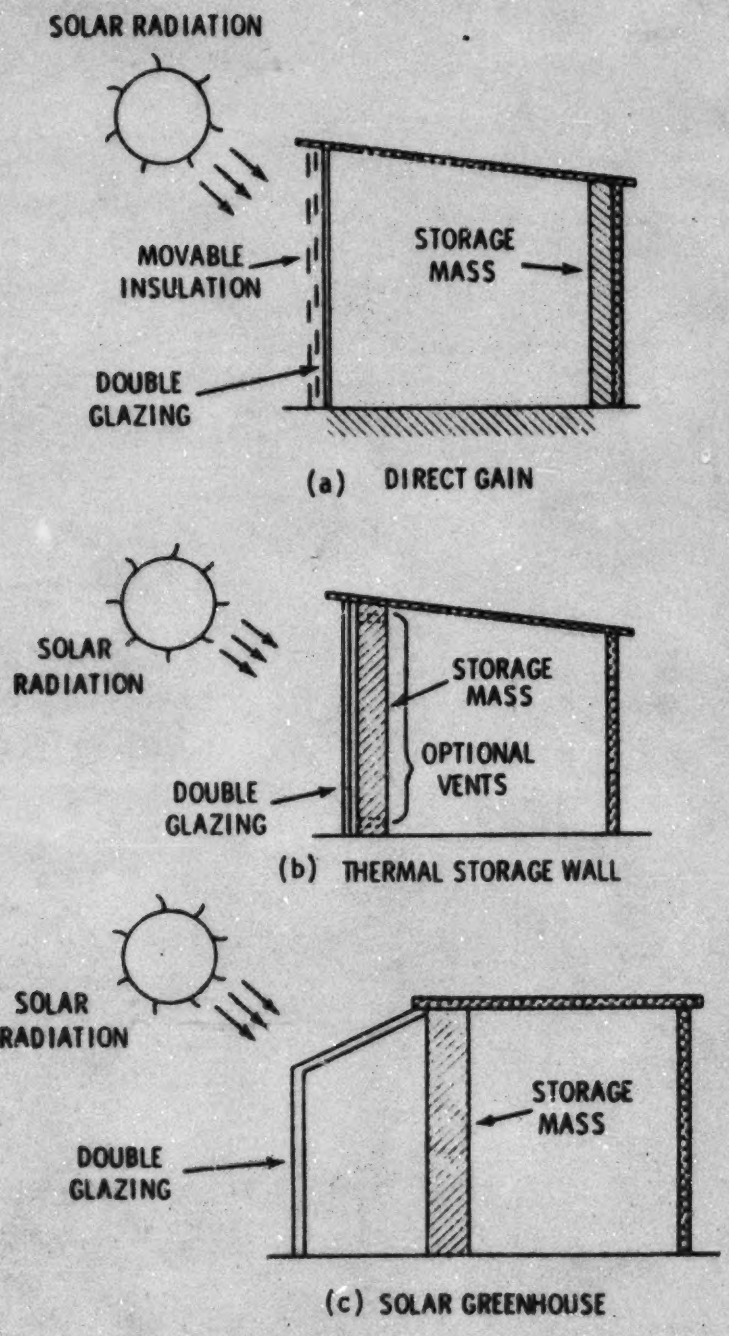

FIGURE III Passive Solar Heating Concepts

boxes are cost effective, the major market for passive designs is presently in new construction. However, the continued escalation in the cost of conventional space heating is rapidly making passive retrofit technologies highly competitive.

SOLAR/PASSIVE HYBRID

This solar technology combines elements of both passive and active systems. The components of a passive hybrid system are identical to an active or passive solar system. They include: a collection area, mass for thermal storage and a distribution system. The basic difference between passive hybrid and an active system is that the collector is a room or space, inthe form of a greenhouse, solarium or other usable living space. Passive hybrids differ from strictly passive systems in that they do employ some form of external energy input to circulate the heat they collect, such as a fan or blower.

One passive hybrid design utilizes an attached greenhouse to collect the sun's energy. Warm air, collected in the greenhouse is then passed through ductwork to a rock bin designed to absorb the heat from this air and return cabled air to the greenhouse space. Figure IV illustrates this approach. Because this system collects the sun's energy at temperatures of about 80 - 90° F, it has a relatively high collection efficiency resulting in a relatively low cost/unit of energy produced.

USE SECTORS - Passive/hybrid solar designs are easily integrated into new buildings as part of the basic architectural design. This makes such designs very cost-effective in new construction.

Passive hybrid designs also are amenable to retrofit installations.

MARKET DEMAND - The market for passive solar has the most near term potential of any solar-based technologies. It is immediately accessible to existing contractors, businesses and homeowners.

In addition, it provides a usable additional space--a greenhouse or sunspace. A preliminary market survey done by Ecotope Group in January 1978 suggested that a market for solar greenhouses in kit form was now available and in the short run a successful small scale business could be designed to supply materials to meet this demand. In this sense, the demand for solar greenhouses alone would reach 200 to 500 per year within five years (above and beyond existing supply). About 100 to 300 consistent jobs developing solar passive hybrid solar homes would be developed.

SOLAR WATER HEATING

Solar water heating is a technology which collects sunlight, converts it to heat and transfers it to the hot water system. There are a variety of approaches used to employ solar energy to heat water. Each component of the system--working fluid, collector, storage and transport mechanisms can take a variety of forms. The fluid used to transfer heat from the collecting device is,

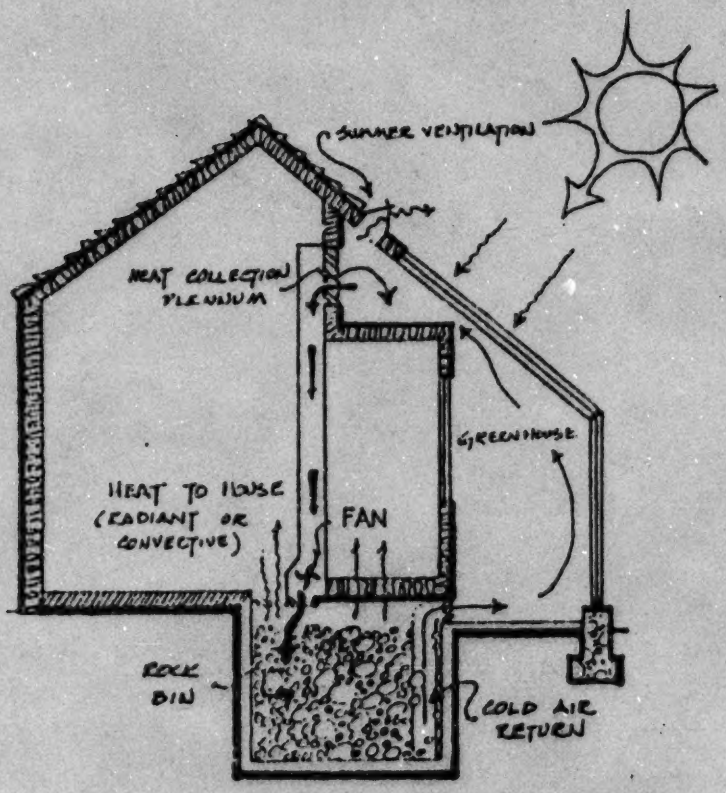

FIGURE IV - Solar Passive/Hybrid Heating Concept

however, generally used to divide solar water heating designs into two broad categories; those which use air and those which employ a liquid. Figure V depicts a typical domestic hot water heating system.

Air systems require heat exchangers to transfer heat from the air to water. This is accomplished either through the use of a radiator or by placing a water tank in the thermal storage (often a rock bin) of an air-based space heating system. Since the net efficiency of air-to-water systems is low the most commonly used water heating technologies are designs to employ liquid working fluids. These systems can heat water by:

1. Circulating it directly through the collector;
2. Circulating an antifreeze solution through the collector and heat exchanger;
3. Circulating freon in a natural convective loop through the collector and heat exchanger (See Figure VI); or
4. Circulating a compressed refrigerant through the collector at a lower than ambient temperature and exchange heat through a heat pump.

The first two approaches are the most widely used.

Within the two broad categories of water heating designs, systems can also be differentiated on the basis of the type of collector they utilize. The collector used in an air systems can be a flat plate collector or a greenhouse collector. In liquid systems the collector can be integral to the storage system such as in Breadbox or Roof Pond direct gain systems, or it can be a separate unit.

Separate collectors can be either flat plate units or concentrating units. Concentrating collectors require direct beam radiation while flat plate collectors use diffuse radiation. Therefore, most concentrating collectors are installed to track the sun.

Flat plate collectors are currently the most widely used for domestic water heating because they can economically produce temperatures up to 140° F. Above this temperature the more expensive concentrating collectors are more cost effective since they experience lower heat losses at higher temperatures. Some high temperature industrial water heating systems use a combination of flat plate collectors and concentrating collectors to optimize efficiency.

The heat energy collected in a direct-gain system is stored within the collector. When separate flat plate collectors or concentrating collectors are used the heat is stored in a separate insulated tank. Hot water from the tank may be tapped directly for use or it may serve as a pre-heating reservoir and feed into a conventional water heater for final heating. Some storage tanks incorporate a make-up heating element in them. However, because this design can negatively impact the performance of the total system it is not frequently used.

Two methods are used to circulate the water through solar hot water heating systems. These are generally referred to as "active and passive" systems.

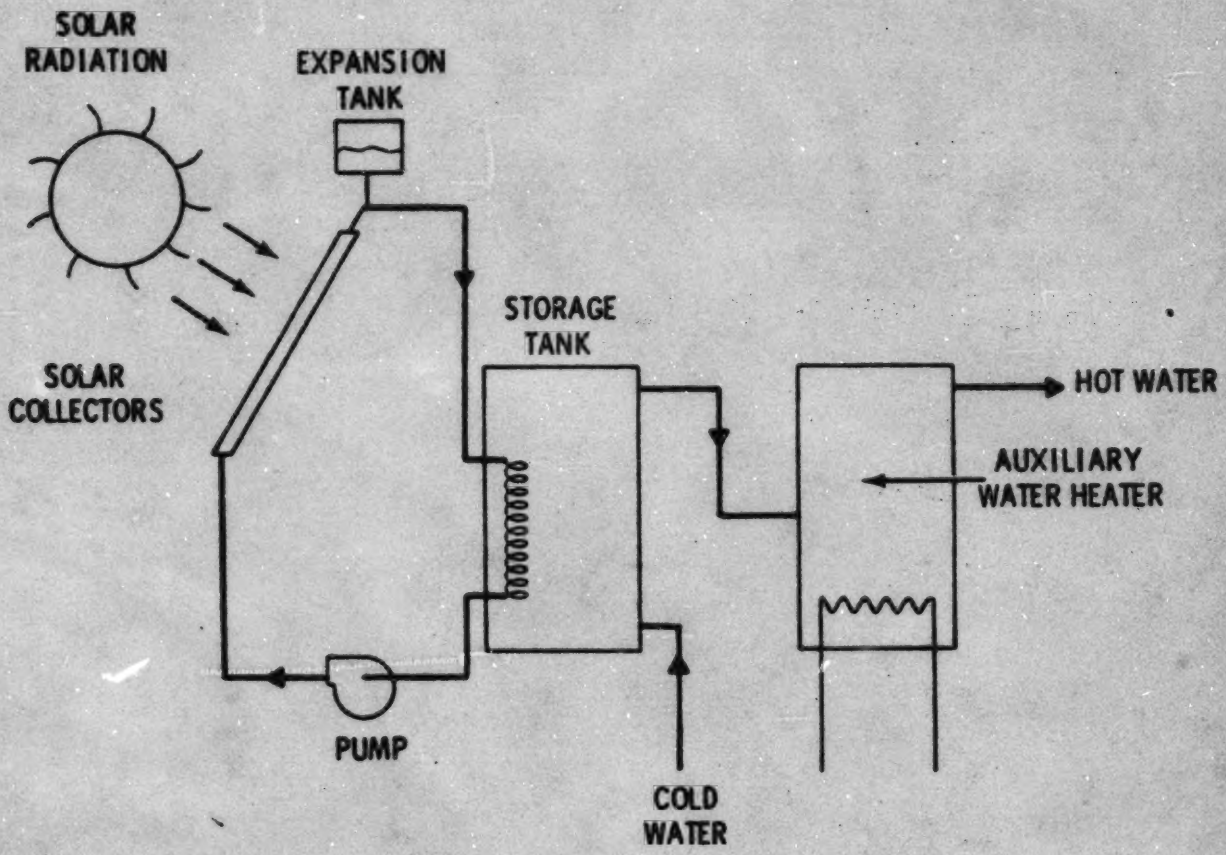

FIGURE V A Solar Domestic Water Heating System

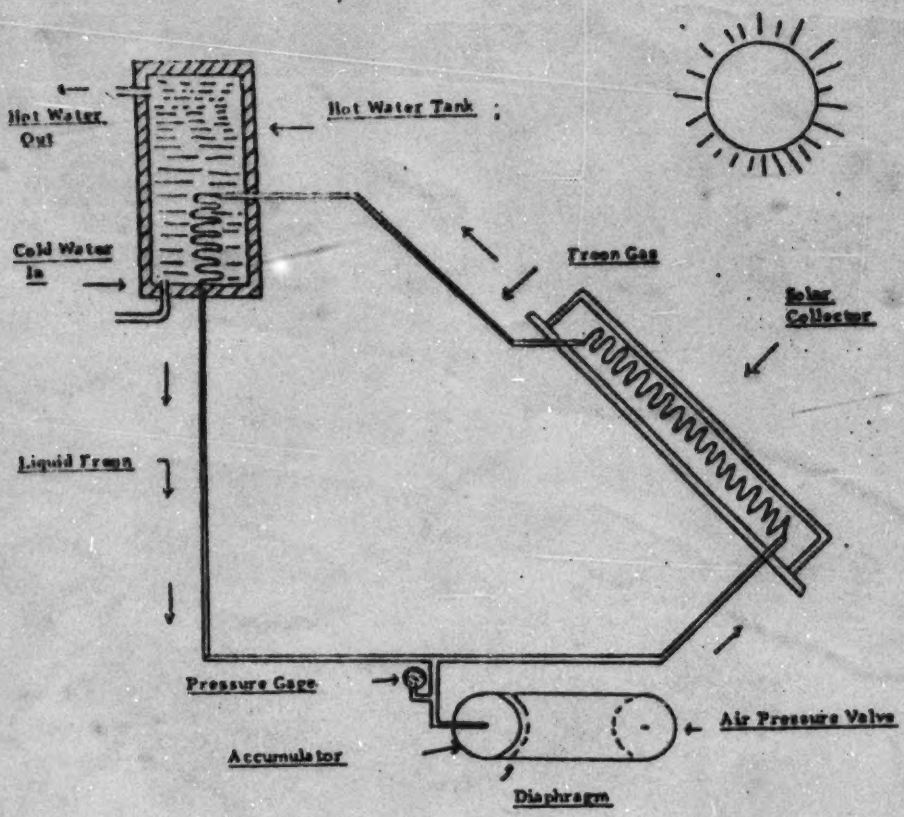

FIGURE VI - Heliophase (Freon) Hot Water Heating System

Active systems compose the bulk of the commercially installed liquid fluid systems and all air systems. Active liquid systems employ pumps which are activated by thermostatic controls. These thermostats also operate mechanical vales which permit the incorporation of drain-out mechanisms into the system to prevent freeze-up. Maintenance of active systems, due to their more complex nature is expected to be more frequent than with passive systems.

The passive, or gravity flow system is called a thermosiphon. The original hot water systems used in the U. S. were thermosiphon systems. In this design the storage tank was traditionally placed at least six inches above the top of the collectors to prevent reverse siphoning. However, with the recent development of a thermic device which closes the water line when the collector temperature falls below a certain point, the tank may now be at the same level. Nevertheless, even with this improvement the installation of a thermosiphon system present structural problems in mounting, supporting and housing the storage tank which active systems do not.

Thermosiphoning systems which use freon as a working fluid operate at pressures which require refrigeration soldering techniques (silver solder) and high quality collector construction. A special pressure-governing device is also necessary in freon systems to avoid overheating. The freon system's major advantage comes from the fact that it is freeze-proof and capable of operating at temperatures below that of water systems.

One of the major design factors in solar hot water heating systems is freeze protection. Solutions devised to cope with this problem include covering the collector with an insulating shell,draining the collectors (either manually or automatically), heating the collector with electrical resistance tape, circulating a antifreeze solution in the collector loop through a heat exchanger in the water supply. All of these choices depend on climate, collector, transport system and site.

USE SECTORS - Domestic solar water heating is currently well developed, with manufacturers, distributors and installers established in many areas. Industrial water heating is currently in developmental stages with pilot projects being carried out by several manufacturers. Hot water systems are now operative in several types of commercial establishments. They are particularly appropriate for use in laundries and restaurants which have a large hot water demand.

MARKET DEMAND - Domestic hot water heatings systems are one of the simplest and least costly methods of using solar energy. The use of such systems is expected to grow substantially over the next decade as convential heating "fuels" grow more costly. Of all domestic uses of solar energy, only passive and passive hybrid approaches to space heating and swimming pool heaters are expected to experience comparable usage in the short term.

SOLAR SWIMMING POOL HEATERS

Solar swimming pool heaters are the most widely used of all solar heating systems in the country. Figure VII shows a typical schematic for a pool heating system. After pool water is pumped through a standard pool filter, it passes through the collector array and then back to the pool. Manual or automatic valves allow the collectors to be bypassed on very cloudy days or at night if it is desired to keep the filter running. The circulation pump is generally the standard pool pump supplied as part of the filter system.

Swimming pool heaters represent an ideal application of solar energy for several reasons:

1. Swimming pools are generally used from late spring to fall when the largest amount of solar radiation is available.

2. Pools already have a pump as part of their filtration system and the pool itself acts as the storage and distribution system. Consequently, the only additional expense for a solar pool heater is the collector array, piping and control system. Indeed, the control system is often no more than a few manual valves to allow diversion of filtered pool water through the collector.

3. Because of the low temperatures and pressures involved, solar pool heaters can use very simple, low-cost unglazed collectors, often made of plastic.

4. The relatively low collector operating temperature results in high collector operating efficiency.

5. Swimming pools do not normally have stringent temperature control requirements. Often the solar pool heater will be installed with no backup system at all. The owner allows the pool to reach whatever temperature it can and if that is still too cold, he simply doesn't swim.

6. Because variations in pool temperature are not a serious problem and because collectors are inexpensive, sizing of a collector system for a pool is not as critical as for a house. For this reason, detailed procedures for sizing pool heaters have not been developed. Instead, the general rule-of-thumb has been to use a south-facing collector area of 50 to 75% of the pool surface area. If the pool stays too cool, collector area can be added. If the pool stays too hot, the collectors can be bypassed. Moreover, in many cases the collector area is determined by the available area of mounting surface or by the amount of material the pool owner has available for his collectors.

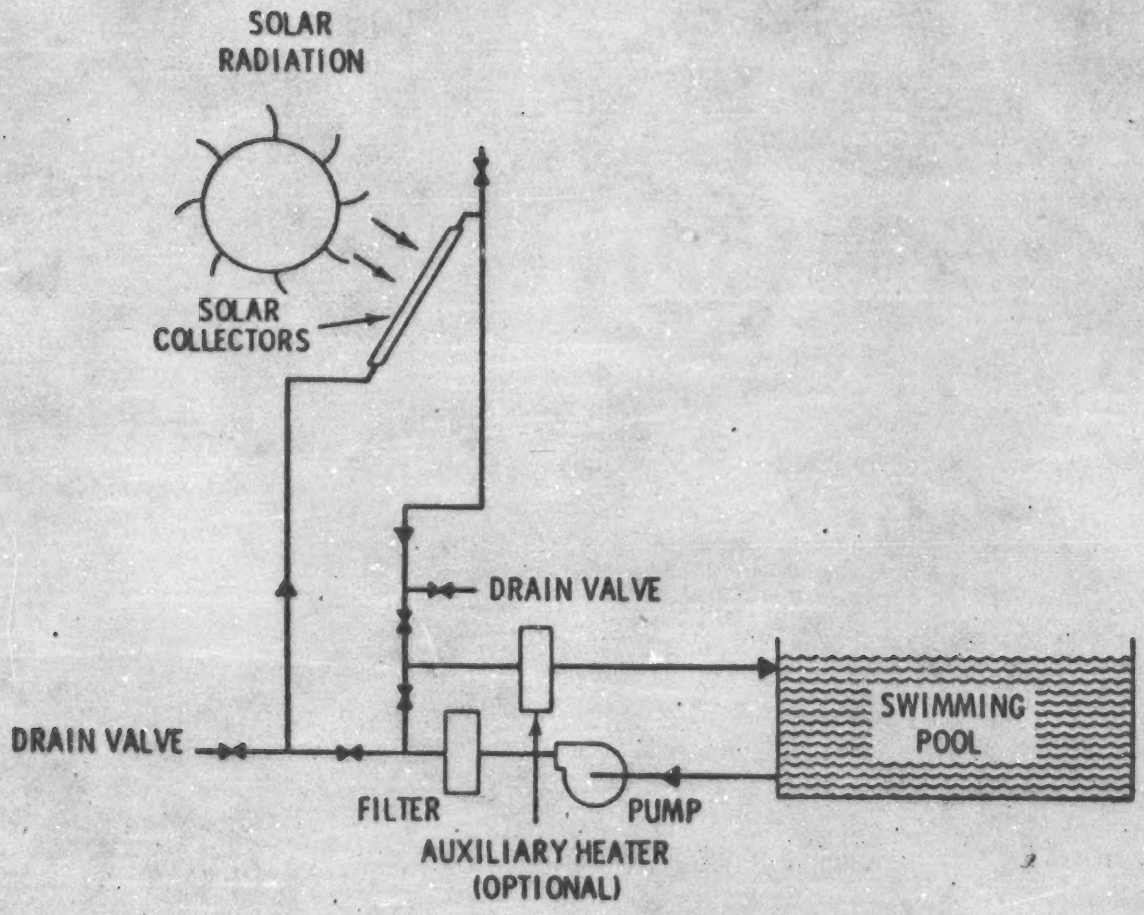

Figure VII - Typical Swimming Pool Heating System

In the Puget Sound region, solar heating of swimming pools are more practical if heat losses from the pool are reduced either by covering the pool with an insulating material and/or building it inside and insulating under the deck and 2' down the sides of the pool. Moreover, if the pool is to be used in the early spring and later fall, performance can be enhanced by glazing collectors.

APPENDIX V

Seattle/Opportunities Industrialization Center

SEATTLE/OIC SOLAR OCCUPATIONS SURVEY
SUMMARY AND ANALYSIS OF RESULTS

10/31/78

INTRODUCTION

Seattle/OIC, as part of a research and curriculum development project in solar energy, conducted a survey to ascertain the nature and extent of solar related employment opportunities in Washington State. A questionnaire was prepared and sent to all of the solar system or component manufacturers, distributors and installers listed in the State by the National Solar Heating and Cooling Information Center.

A total of 47 questionnaires were mailed. Thirteen completed questionnaires, or approximately 28% were returned. Another 6% (three questionnaires) were returned as not being deliverable.

While implications drawn from data developed from these returned questionnaires are statistically valid, (i.e., the sample size is sufficiently large to represent the population) they should not be accepted as absolutes. Nevertheless, they do represent the only available information known to Seattle/OIC on the status of the solar industry specifically for Washington.

RESULTS

Most of the firms surveyed indicated that they were engaged in multiple functions. Forty-six percent of the companies completing questionnaires provided design and retail distribution services. Approximately one-third of those surveyed were engaged in wholesale distribution, and one-fifth were involved in the manufacture and installation of solar systems. Only one firm of those responding indicated that it provided system maintenance services.

More than three quarters of the firms responding handled domestic hot water systems, and over sixty percent carried swimming pool heaters and active-air space heating systems. Greenhouses were available from about one-half the firms. Active water

This paper was prepared under a project partially funded by the Washington Commission for Vocational Education. The views and conclusions contained in this document, however, do not necessarily represent those of the Commission or its staff.

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space heating systems, commercial hot water heating systems, and passive space heating components were available from slightly more than one-third of the firms responding. Two firms indicated they handled mobile home solar components, and one firm carried tracker heliostats.

The ranking of technologies expected to experience high demand during the next two to five years parallels the number of firms carrying those technologies. During the next two to five years domestic hot water and swimming pool heating systems were judged by those surveyed to achieve the greatest use. Passive heating systems, including greenhouses, were expected to achieve the next greatest use. Respondents felt that active-air space heating systems would also receive wide-spread adoption. Other systems mentioned in order of anticipated use include: active water space heating systems, thermal and concentrating photovoltaics, and commercial hot water heating units.

Sheet metal workers were identified by 85 percent of the respondents as being the occupation most needed to install and maintain solar systems/equipment. Carpenters, plumbers and electricians were also identified as occupations required for solar system installation and maintenance. One-fifth of those surveyed felt that glaziers and refrigeration and air conditioning technicians would experience some increased demand as a result of solar system use.

Sheet metal workers, carpenters, and plumbers were the occupations most frequently employed full-time by those firms responding to the survey. Other occupations mentioned included glaziers, electricians, mechanical designers, general contractors and "committed solar entrepeneurs."

Several firms indicated that they hire or subcontract with tradespeople based on their sales. These firms did not maintain a large number of full-time staff because the present demand for solar systems did not justify a large labor force. The salary for entry level employees hired to manufacture solar systems/equipment ranged from $4.00 per hour to more than $7.50 per hour. The average wage for solar system manufacturers was between $5.00 and $5.50 per hour.

Seventy-three percent (73%) of those responding to the survey expected new occupations to evolve in the installation, maintenance or manufacture of solar systems/equipment.

The large majority of these respondents expected a "solar technician" occupational category to surface. Individuals filling these positions would be capable of doing both design and installation work involving a variety of building trade skills such as sheet metal, carpentry, plumbing and electrical wiring. The remaining 27% indicated that they felt no new special occupations would evolve.

Twelve individuals are presently employed that fit into this "solar technician" category. An additional nine more are expected to be hired within the next 18 months. The salary range for solar technicians appears to be from $4.00 per hour to more than $7.50 per hour, with an average wage of between $5.75 and $6.00 per hour.

To qualify for work in the solar field an individual must possess knowledge of building codes; experience and knowledge in plumbing, carpentry, sheet metal, electricity and/or general shop skills; knowledge of various solar systems and their installation and maintenance; and, the ability to work with small hand and power tools.

The personal qualities of solar workers desired by firms surveyed included neat appearance, enthusiasm, honesty, mechanical aptitude, sense of humor and pleasant personality. The technician must have no fear of heights.

Eight of the firms surveyed indicated that they subcontracted with other companies or individuals to install and/or maintain solar systems. The firms listed include:

Northwest Solar Systems
7700 12th St. N.E.
Seattle,

B & B Heating
1730 19th N.W.
Issaquah

Streamline Plumbing
Spokane

Fisher Homes
10060 132nd N.E.
Kirkland

Solar N.W. Corporation
P.O. Box 518
Long Beach, WA. 98631

Three firms indicated that they subcontract with other companies/individuals to manufacture solar systems equipment. Of these, two were located out of state and the third supplied a list of thirty individuals in Washington who serve as subcontractors.

Respondents indicated a strong preference for job applicants with both vocational training and considerable experience and a moderate preference for individuals with vocational training and some experience.

Present employees of solar energy firms come primarily from universities or are past acquaintances of members of the firm. A few (11%) of those employed were hired "off the street."

ANALYSIS

It appears that a fledgling solar industry is developing in Washington State. As of April, 1978 nearly 50 firms were engaged in some phase of solar system design, sales, manufacture, installation and/or maintenance. Currently, the preponderance of these firms are operating their solar business as a "sidelight" to an existing enterprise. However, there are a few "cottage industry" firms specializing in solar technologies exclusively. These firms, while not thriving, appear at least to be surviving.

The solar technologies carried by Washington's solar industry reflect the generally perceived market potential of those technologies. Both academic research and common wisdom rank domestic hot water, swimming pool heaters and passive designs (e.g. attached greenhouses, trombe walls, etc.) as being the most economically viable near term solar technologies for most of the Pacific Northwest.

Not surprisingly, survey respondents identified the occupations now performing installation and maintenance work such as sheet metal workers and plumbers, as those which will be performing such work in the future. However, nearly three quarters of those responding to the survey also felt that a "solar technician" job category would eventually evolve as the number of solar installations grew. This technician would have design skills as well as a mastery of the basic construction trade skills.

Indicative of the infant nature of Washington's solar industry is the fact that most of the survey respondents did not maintain full time installation and maintenance crews. To reduce (or avoid) overhead costs, most firms offering installation services subcontracted

with craftspeople as needed. At present this strategy appears to be justified by the current level of demand for solar systems and equipment. As demand grows, more full time staff positions may be established.

While salary offerings varied over a wide range, the minimum wage offered to solar workers was competitive with entry-level employment in the construction trades. Moreover, the skills, knowledge and training (excluding solar system design) also appear to be consistent with entry level requirements in the construction crafts. Individuals possessing "solar specific" skills such as design and/or diagnostic abilities which would qualify them as "solar technicians" or "mechanics" did command somewhat higher wages (in some cases more than double) than the "Entry Level" solar worker.

While it is dangerous to extrapolate the anticipated number of openings for solar workers and "technicians" from this limited survey, the lack of any more reliable estimates necessitates doing so. Assuming a strictly linear relationship between those firms responding and others in Washington's solar industry, there appears to be a need for approximately 14 solar installers and maintenance personnel and 31 "solar technicians" state-wide during the course of the next eighteen months. The magnitude of this expansion, when compared to the labor market for the general construction trades appears inconsequential.[1] However, individuals receiving solar augmented training as part of basic vocational instruction will have a more diverse set of marketable skills. They will, therefore, potentially be able to take advantage of employment opportunities which are expected to develop as the solar market expands.

Since no other studies have evaluated the potential labor market for solar technicians, it is impossible to determine the reliability of the thirty one "openings" estimated by this study. As regards Seattle/OIC, the length of training required to exit with the "solar technician" skills desired by practicing firms appears to be substantially beyond present curriculum offerings. Therefore, the accuracy of this estimate may not be as crucial as it would be were skills training beyond entry level a major organizational thrust. Nonetheless, since the demand for solar technicians could be met by providing advanced training to indivduals currently employed the estimate is of value.

1. The total demand for carpenters in the King-Snohomish Manpower Consortium service area alone is estimated at over 300 during 1978 - 79.

APPENDIX IV

Seattle/Opportunities Industrialization Center

July 14, 1978

Dear Solar System Suppliers, Manufacturers and Installers:

Seattle Opportunities Industrialization Center (Seattle/OIC) is a community based, non-profit vocational training and job placement organization. Its primary purpose is to counsel, train and place economically disadvantaged individuals in entry-level occupations. Our present curriculum provides training in eleven areas, including carpentry, plumbing, electrical maintenance, welding and clerical skills.

Seattle/OIC recently initiated a research project to assess the employment potential resulting from the deployment of solar energy systems. Through this project we hope to identify the type and number of job opportunities created by the use of solar energy and ultimately develop an appropriate vocational curriculum to train individuals to fill those jobs.

As part of our research we are asking individuals actively involved in the solar field to share their personal evaluation of the near term (2-5 years) labor demand in solar related occupations. We would greatly appreciate your taking a few minutes to complete the enclosed questionnaire. Your answers to these questions will ensure that our program will be "appropriately scaled" and "matched in quality" to solar occupations.

Once you have completed the questionnaire please place it in the return envelope provided. Be assured that all responses will be kept in confidence and that no person or firm will be identified individually.

Thank you in advance for taking time to complete this questionnaire. If you desire a summary of the completed survey, please indicate so by checking the appropriate space and supplying your name and address on the questionnaire.

Should you have any questions about the questionnaire or Seattle/OIC's solar project, please feel free to contact me or Tom Eckman of my staff at the address below or (206) 223-2828. Again, thank you.

Sincerely,

John Charles
Assistant Director

Enclosures

315 · 22ND AVE. SO. · SEATTLE, WASHINGTON 98144 · 206 / 223-2828

SOLAR OCCUPATIONS SURVEY

THE PURPOSE OF THIS SURVEY IS TO DETERMINE WHAT TYPES AND HOW MANY JOBS WILL BE CREATED IN WASHINGTON STATE BY THE USE OF SOLAR ENERGY SYSTEMS DURING THE NEXT TWO TO FIVE YEARS. YOUR ASSISTANCE IN COMPLETING THIS SURVEY WILL AID SEATTLE/OIC IN ITS PLANNING EFFORTS. PLEASE ANSWER THESE QUESTIONS IN A FRANK AND CANDID MANNER AS WE DESIRE A REALISTIC ASSESSMENT OF THE LABOR NEEDS ASSOCIATED WITH THE USE OF SOLAR ENERGY.

THOSE QUESTIONS THAT DO NOT APPLY TO YOU OR YOUR FIRM ANSWER BY INDICATING "N/A" IN THE SPACE PROVIDED.

PLEASE COMPLETE AND MAIL THIS QUESTIONNAIRE BY July 31, 1978.

1. WHAT IS THE PRINCIPAL FUNCTION OF YOUR COMPANY? (CHECK ONE)

   ___ DESIGN ___ MANUFACTURE ___ DISTRIBUTION (WHOLESALE) ___ DISTRIBUTION (RETAIL)
   ___ INSTALLATION ___ MAINTENANCE ___ OTHER (PLEASE SPECIFY) _____

2. WHAT TYPES OF SOLAR SYSTEMS/EQUIPMENT DO YOU HANDLE? (CHECK ALL THAT ARE APPROPRIATE.)

   ___ DOMESTIC HOT WATER ___ COMMERCIAL HOT WATER ___ SPACE HEATING-ACTIVE AIR
   ___ SPACE HEATING-ACTIVE WATER ___ SPACE HEATING-PASSIVE COMPONENTS ___ SWIMMING POOL HEATERS
   ___ GREENHOUSES ___ MOBILE HOME SOLAR COMPONENTS ___ OTHER (PLEASE SPECIFY) _____

3. WHICH SOLAR SYSTEMS EQUIPMENT DO YOU FEEL WILL ACHIEVE THE GREATEST USE DURING THE NEXT TWO TO FIVE YEARS IN WASHINGTON STATE? (INDICATE TOP THREE)

   GREATEST USE _____

   SECOND GREATEST USE _____

   THIRD GREATEST USE _____

4. WHICH OCCUPATIONS LISTED BELOW WILL MOST LIKELY BE INVOLVED IN THE INSTALLATION AND MAINTENANCE OF THOSE SOLAR TECHNOLOGIES ACHIEVING THE MOST WIDE SPREAD USE DURING THE NEXT TWO TO FIVE YEARS IN WASHINGTON STATE? (INDICATE TOP THREE)

   ___ CARPENTER ___ PLUMBER ___ SHEET METAL WORKER ___ ELECTRICIAN ___ GLAZIER
   ___ REFRIGERATION & AIR CONDITIONING TECH. ___ OTHER(S) (PLEASE SPECIFY) _____

5. HOW MANY INDIVIDUALS DO YOU OR YOUR FIRM PRESENTLY EMPLOY IN EACH OF THE FOLLOWING OCCUPATIONS TO INSTALL AND MAINTAIN THE SOLAR SYSTEMS/EQUIPMENT YOU HANDLE?

   ___ CARPENTER ___ PLUMBER ___ SHEET METAL WORKER ___ ELECTRICIAN ___ GLAZIER
   ___ REFRIGERATION & AIR CONDITIONING ___ OTHER (PLEASE SPECIFY) _____

6. HOW MANY NEW EMPLOYEES DO YOU OR YOUR FIRM EXPECT TO HIRE DURING THE NEXT 18 MONTHS IN EACH OF THESE OCCUPATIONAL AREAS TO INSTALL AND MAINTAIN THE SOLAR SYSTEMS/EQUIPMENT YOU HANDLE?

   ___ CARPENTER ___ PLUMBER ___ SHEET METAL WORKER ___ ELECTRICIAN ___ GLAZIER
   ___ REFRIGERATION & AIR CONDITIONING TECH. ___ OTHER (PLEASE SPECIFY) _____ ____.

7. WHAT IS THE SALARY RANGE FOR AN ENTRY-LEVEL EMPLOYEE YOU EMPLOY TO INSTALL AND/OR MAINTAIN THE SOLAR SYSTEMS/EQUIPMENT YOU HANDLE?

   ___ $2.50 - $3.00/HR ___ $4.00 - $4.50/HR ___ $5.50 - $6.00/HR ___ MORE THAN $7.50/HR
   ___ $3.00 - $3.50/HR ___ $4.50 - $5.00/HR ___ $6.00 - $6.50/HR
   ___ $3.50 - $4.00/HR ___ $5.00 - $5.50/HR ___ $6.50 - $7.00/HR

8. WHICH OCCUPATIONS LISTED BELOW WILL MOST LIKELY BE INVOLVED IN THE MANUFACTURE OF THOSE SOLAR TECHNOLOGIES ACHIEVING THE MOST WIDE SPREAD USE DURING THE NEXT TWO TO FIVE YEARS IN WASHINGTON STATE? (INDICATE TOP THREE)

   ___ CARPENTER ___ PLUMBER ___ SHEET METAL WORKER ___ ELECTRICIAN ___ GLAZIER
   ___ REFRIGERATION & AIR CONDITIONING TECH. ___ OTHER (PLEASE SPECIFY) _____
   _____ _____

9. HOW MANY INDIVIDUALS DO YOU OR YOUR FIRM PRESENTLY EMPLOY IN EACH OF THE FOLLOWING OCCUPATIONS TO MANUFACTURE THE SOLAR SYSTEMS/EQUIPMENT YOU HANDLE?

13. How many individuals do you or your firm presently employ that fit this new occupational category?

_____

14. How many individuals do you or your firm expect to hire in the next 18 months that fit into this new occupational category?

_____

15. What is the salary range for an entry-level employee in this new occupational category? (Check one)

___ $2.50 - $3.00/hr ___ $4.00 - $4.50/hr ___ $5.50 - $6.00/hr ___ $7.00 - $7.50/hr
___ $3.00 - $3.50/hr ___ $4.50 - $5.00/hr ___ $6.00 - $6.50/hr ___ More than $7.50/hr
___ $3.50 - $4.00/hr ___ $5.00 - $5.50/hr ___ $6.50 - $7.00/hr

16. What are the minimum requirements (e.g., skills, knowledge, experience, training, degrees) you or your company have for entry-level positions in the occupational areas employed to install and maintain the solar systems/equipment you handle? (Feel free to attach more sheets if necessary.)

17. What non-skill pre-requisites must an individual possess to qualify for employment as an installer or maintenance person of the solar systems/equipment you handle? (e.g., no fear of heights, physical strength, or allergies)

18. Do you or your firm sub-contract with other companies/individuals to install and maintain the solar systems/equipment you handle?

___ Yes ___ No If yes, we would like to contact this firm to ascertain their labor needs. If possible, would you please provide their address below:

19. What are the minimum requirements (e.g., skills, knowledge, experience, training, degrees, etc.) you or your company have for entry-level positions in the occupational areas employed to manufacture the solar systems/equipment you handle? (Feel free to attach more sheets if necessary.)

20. What non-skill pre-requisites must an individual possess to qualify for employment to manufacture the solar systems/equipment you handle? (Feel free to attach more sheets if necessary.)

Seattle Opportunities Industrialization Center

AN ASSESSMENT OF NEED FOR DEVELOPING AND IMPLEMENTING VOCATIONAL TRAINING FOR THE SOLAR ENERGY INDUSTRY IN WASHINGTON STATE

10/31/78

A LITERATURE REVIEW

Compiled By
Tom Eckman - Research Curriculum Development Specialist

INTRODUCTION

In order for the solar industry to be successful in stimulating commercial use of solar energy, it must provide for the development of manpower resources with the knowledge and skills to install and maintain solar systems. The significance of the demand for solar equipment and solar workers must be known before plans can be made to develop a curriculum to train these workers. There should be a well founded expectation that there will exist a clear demand for the training, and employment opportunities for the graduates of the training program. Heretofore, there have been insufficient data available regarding the number of solar energy workers that could be employed in this new and emerging field.

This paper reports the results of a preliminary literature review conducted to determine both the national need and the need in Washington State for manpower trained in solar energy technology. A secondary objective of this survey was an attempt to identify the tasks that should be performed by solar workers. This information will aid in manpower population determination and solar curriculum design.

The scope of this review is limited exclusively to all low temperature (below 300°F) applications of radiant solar energy for space heating and cooling.

This paper was prepared under a project partially funded by the Washington Commission for Vocational Education. The views and conclusions contained in this document, however, do not necessarily represent those of the Commission or its staff.

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This limitation was established based on a study done by the University of Texas which indicated that 45% of all energy applications in this country are under 500°F, and 53% of the energy uses to be no higher than 150°F. This temperature limit would exclude, for example, utility type (centralized power generation) training. However, it does include those technologies such as space and water heating, which are now well developed and in the market place.

The results of this literature review have been divided into three sections:

Section I - Projections of Expected Demand for Solar Systems

It is the basic assumption of this project that the demand for solar manpower is a direct function of the demand for solar equipment. Existing studies national, regional and representative special forecasts are reviewed.

Section II - Projections of National and State Manpower Demand in Solar Energy. This section reviews existing projections of manpower demand which are national, regional or state specific in scope. It also reviews studies commissioned or conducted by special interest groups, such as labor unions.

Section III - Task Analysis of Solar Occupations

This section identifies the steps typically performed in the installation and maintenance of a generalized solar system. This portion of the review seeks to determine the expected time required to perform these tasks and identify the tradesperson who normally or traditionally might perform that task.

SECTION I - PROJECTIONS OF EXPECTED DEMAND FOR SOLAR SYSTEMS

Three national studies which forecast the expected market penetration of solar energy systems have been prepared since 1976. These studies were conducted by the University of New Mexico,[1] the MITRE Corporation,[2] and the Solar Energy Industries Association (SEIA).[3]

The SEIA study is the industry's own estimate of its market potential. As such it represents the views of those who must directly gain or lose depending on the accuracy of their perceptions.

The MITRE study is the product of the most intense effort to date by the Energy Research and Development Administration (now Department of Energy - DOE) to arrive at feasibility and market penetration estimates. MITRE estimates are being used extensively by DOE in many other analyses.

The University of New Mexico (UNM) study forecasts the economic feasibility of solar energy state-by-state, by year, and by application. Due to exogenous variables, such as orientation and structure, freedom from obstacles, and age of the structure, economic feasibility is not readily translated to market penetration. As a result, the UNM study represents an economic upper limit and not a forecast of penetration.

All three studies provided regionalized results. MITRE used climatological data from sixteen different cities (including Seattle) that represent sixteen different zones. SEIA similarly selected several regions for analysis by state and by year.

The fraction of the total housing market expected to have solar systems installed, when it is economically feasible to do so, is called market penetration. The projected demands - or market penetration - for solar equipment is substantial based on the three studies reviewed. All three studies agree that by 1985 there will be at least 2.4 million solar hot water/space heating units installed in the residential sector of the United States.

On "Sun Day" President Jimmy Carter ordered a cabinet level review of Domestic Solar Policy. This review developed three scenarios of future solar energy use for the year 2000(4) The"base case" forecast assumes that Federal Solar policy will be as stated in the National Energy Act and oil will cost $25/barrel. In this scenario, by the year 2000, about 1/8 of the new dwellings (between 5 and 6 million) will be constructed with passive solar designs or with an active space and hot water systems. An additional 11 million will be retrofitted with hot water systems. Thus, solar heated homes would account for about 13 percent of all new construction over the next two decades, and about 6% of all new homes existing in the year 2000.

In the "Maximum Practical Case", about 22 million homes are anticipated to be solar heated--or about 50% of those to be built. There would also be about 19 million solar hot water systems under this scenario by the year 2000. The "Technical Limit" for solar, according to the Domestic Solar Policy Review staff appears to be about 37 million solar heated homes, half of them actively and half passively. This necessitates solar heating in about 80 percent of all new homes built between now and the turn of the century.

In a background paper prepared for the Pacific Northwest Utilities Conference Committee long range electrical forecast, Liffick estimated the proportion of new and retrofit solar space and hot water system usage for the Pacific Northwest[5]. He forecast that by 1990 approximately 5% of the regions pre-77 residential structures and 30% of the region's new construction would have solar hot water systems. By the year 2000 Liffick estimated that 10% of existing dwelling and 60% of new residential dwellings would have solar hot water heating systems.

Liffick's residential space heating projections indicate that in 1980 10% of the regions new residential structures will be solar heated. This

proportion increases to 20% in 1990 and 50% by the year 2000. He estimates retrofit space heating systems application to occur in 1% of the pre-1977 residences by 1990 and only 5% by the turn of the century.

The Northwest Energy Policy Project's "most probable" forecast, estimates that by the year 2000 there will be 3.7 million households in the Pacific Northwest. Using this figure and Liffick's estimates,the number of residential structures that will employ solar hot water heating systems can be calculated. These calculations reveal that at the turn of this century approximately 830,000 new homes and 227,000 existing homes will have solar hot water systems. Additionally solar space heating will be placed in nearly 690,000 new homes and retrofitted onto 114,000 existing houses in the Northwest.

SECTION II - PROJECTIONS OF NATIONAL AND STATE MANPOWER DEMAND IN SOLAR ENERGY

The Department of Energy contracted with Navarro College to assess the manpower demands produced by the MITRE, SEIA and UNM market penetration forecasts.[7] Using data from the SEIA study, Navarro College estimated that 80,000 practicing solar workers will be needed by 1985. Using data from the University of New Mexico, the Navarro College study forecast a demand for 40,000 people in the solar field by 1985. The most conservative calculations, using data from the MITRE study, indicate 25,000 people will be working in the field by 1985.

By 1990, the total manpower demand increases to a minimum of 50,000 using MITRE and UNM data, and 325,000 using the SEIA forecast.

In addition to the MITRE, SEIA and University of New Mexico studies, parallel research projects have been commissioned by labor unions. Two of these studies with national scope were conducted in 1975 for the Sheet Metal Workers. International Association. [8,9] These studies indicated that solar heating and

and cooling could provide 15,000 jobs for sheet metal workers by 1990. The Solar Energy Domestic Policy Review panel also estimated the cumulative labor requirements of various solar policies over the next 22 years.[4] In their base case estimate they projected 4.4 million labor years of work, half of which are generated by the deployment of solar hot water, space heating and cooling. The labor requirement under the Domestic Policy Review teams "Maximum Practical" case is 12.7 labor-years and under for their "Technical Limit" it is 25.3 million labor years.*

One other major study having national scope was prepared for the National Science Foundation (NSF) to determine the sector - specific sales and employment impacts of a large scale solar space and water heating industry.[10] This study did not directly estimate the impact on specific trades, such as carpentry, plumbing or sheet metal. However, it did conclude that approximately 200 million dollars would be paid to compensate labor directly involved in solar industry in 1985. The NSF study also identified the four sectors of the economy which it forecast to experience the largest increase in employment. These were those engaged in the various stages of metal production and fabrication; those producing glass, wood and plastics; and those engaged in the manufacture of general industrial machinery and scientific labor and controlling instruments. These four sectors are projected to experience employment changes greater than one percent of their baseline labor force.

Solar-energy related manpower forecasts on a state-specific basis have only recently begun to appear. Two of the most extensive analysis have been conducted for the State of California. The first of these was prepared by the State's Employment Development Department (EDD) in an effort to access

*The Domestic Policy Review panel's estimates do not represent net jobs created, however, because they do not take into account labor market competition or the jobs displaced in the areas of conventional fuel supply. These data are expected to be estimated in the final report.

the comparative labor requirements of meeting equivalent energy needs with solar units versus centralized electric power plants.[11] It also analyzed the employment consequences of solar legislation currently being considered by Congress and the California State Legislature.

EDD cited information developed by the Jet Propulsion Laboratory,[12] which calculated that a tax incentive similar to one passed in 1977 by the California State Legislature would lead to the installation of 60,000 solar units and generate 180 installation and manufacturing jobs for four years. Therefore, EDD concluded, that until solar energy has had the opportunity to develop into a major supplier of energy in California, it will not employ a significant number of that State's ten million workers.

However, in comparing the employment effects of building electric power plants and installing their solar energy equivalent EDD found that the solar option would produce between 6 and 28 times more person-hours of employment. Moreover, most of the direct labor for both power plant construction and solar installation would be performed by construction workers. The average wages of both alternatives would therefore be about the same.[13]

A second study, conducted by the California Public Policy Center (CPPC) projected a substantially greater employment impact of solar than did the Employment Development Department analysis.[14] CPPC estimated that feasible uses of solar energy for space and water heating between 1981 and 1990 could generate 376,815 jobs annually (both direct and indirect employment). Of the direct solar jobs, 21.4% would be in manufacturing, 58.6% installation and 20% in distribution. Indirect/induced employment accounts for 63.7% of the total jobs created. These 376,000 jobs would have reduced California's unemployment rate of 7.8% in 1977 by one half.

The CPPC study believes its estimates to be conservative because it limited its analysis to the job creation potential of active solar space and water heating systems only. It did not consider the employment impacts of wind power, solar thermal electric, biomass conversion, or photovoltaic electricity.

To date no Washington specific manpower projections have been conducted to assess the impact of solar energy deployment on jobs. The manpower forecast derived by Navarro College from the MITRE and University of New Mexico (UNM) studies show no solar related employment in Washington through 1990. This is a result of the conclusions reached in both the MITRE and UNM studies that solar energy use is not economically justified in Seattle (and Washington State) due to low electric rates. This assertion has been the subject of considerable debate.[15]

SECTION III - PRELIMINARY TASK ANALYSIS

The installation of solar energy systems involves tasks associated with various components. A typical system includes a solar collector, which may be fixed or tracking, and may receive either focused or direct sunlight. Such collectors may use a liquid or a gas. In addition to the collector, the design includes piping, pumps, and controls for liquid systems; or ductwork, fans and controls for gas systems. A liquid system may include a storage tank, and a gas system may include an analogous storage (e.g.,rocks). Because solar energy designs are often arranged to supplement conventional heating and cooling systems, and may be installed in new facilities along with conventional systems, the person who installs solar energy devices must also be familiar with heating and/or air conditioning systems.[17]

In the installation of solar energy systems, the trained person will be expected to assemble, start up, and test a delivered system, following written and verbal instructions. These instructions should include a drawing or sketch showing the location of each unit, the orientation of each unit with respect to the structure in which the system is being installed, specifications of piping, ductwork, controls, and wiring required, the start-up procedures, and tests and criteria to determine if the system is operating properly. The individual should also possess sufficient understanding of solar systems in order to resolve unanticipated problems.

The person should be able to measure angles and use this ability to determine proper orientation of solar collectors in an installation; fabricate the supporting brackets or structure for a collector, and install the collector using them (this requires the ability to work metal, such as drill, cut, bend and fasten); install flashing and other materials to prevent leaks around components of the collector through the supporting structure; and install the proper amounts of insulation as backing for the collector, if needed. If collectors include a tracking mechanism, linkages must be installed.

Other components of a solar energy system which involve tasks different from the installation of conventional HVAC designs are the piping, pumps, controls, and control wiring. These generally will involve water with plastic, copper, or steel piping with dielectric unions. Water storage tanks must be installed as components of the system. If it involves air instead of water, an alternate system of ductwork, fans, controls, and storage components must be installed.

The person installing a solar system must be able to apply insulation to pipework or ductwork effectively. He or she must be able to provide air venting on water lines and be able to test piping systems for leaks.

The person must be able to make the necessary wiring connections within the system so that when power connections are made by an electrician the system will function as designed. The person should also be able to prepare the system for startup, and then he or she must run routine operational tests to determine if the system is functional.

Routine maintenance is also a required task. This involves cleaning collector surfaces, checking for water leaks (or air leaks for gas systems), oiling motors and other mechanical parts, replacing belts and setting proper belt tensions, charging and bleeding systems and conducting other routine maintenance procedures.

Advanced maintenance tasks include the diagnosis of problems in the system and the performance of appropriate adjustments and repairs. The diagnostician must have skills and knowledge of measurements. This includes identification and use of instruments, and interpreting the results of their use to determine the cause of problems within the system. Typical instruments would include those which measure temperature, pressure and flow rates.

A solar maintenance person or mechanic must be able to interpret the results of the measurements in terms of the normal operation of the system (based upon standard or baseline measurements for the system). Repairs might involve leaks, corrosion, contaminants, etc. Adjustments might include valves, thermostats, or tracking mechanisms. A procedure, such as descaling for water systems, might be needed in which case this person would carry out that procedure.

The diagnoses the solar maintenance person or mechanic must perform requires that he or she fully understand the function of the system and the principles of its operation. In addition, the person must be able to think analytically about the system.

Solar installations provide the largest amount of direct solar jobs. A large number of employee-hours (eh) are necessary to install each system on a specific site. The job of solar installation as described above cannot be easily automated, although development of solar systems modules would, theoretically, somewhat reduce labor time.

An informal survey, reported by the California Employment Development Department, found that approximately .36 eh/ft^2 of collector were required for new buildings, and .61 eh/ft^2 of collector were needed for retrofit installations.[8] Both of these figures are somewhat higher than those found in the "Jobs from the Sun" study.[14] This study which surveyed manufacturers and installers in California-found the following installation times:

- .429 eh/ft^2 of collector for retrofitting water heating systems on single-family residences, or 20.59 employee-hours for a typical 48 ft^2 unit.
- .32 eh/ft^2 of collector for installing space and water heating systems on new single-family residences, or 126.4 employee-hours for the typical 395 ft^2 unit.
- .453 eh/ft^2 of collector for retrofitting space and water heating systems on single-family residences, or 178.94 employee-hours for a typical 395 ft^2 unit.

These figures, however, were somewhat lower than those reported in a Jet Propulsion Laboratory Paper.[12] Analyzing a 36 ft^2 collector on a water heating system for a single-family dwelling, the JPL found 11 hours of plumbing and electric work, and 4 hours of carpentry and concrete work. This works out to .417 eh/ft^2 of collector for new water heating installations, which the JPL suggests should be doubled to .834 eh/ft^2 of collector for

single-family water retrofits. The "Jobs from the Sun" study is significantly lower (.429 eh/ft^2) for single family water retrofits.

Another study, conducted for the Department of Energy by Navarro College surveyed firms and consultants directly involved in solar system design installation and maintenance.[7] Solar firms contacted by this study indicated that typical design times for domestic hot water systems ranged between 15 and 18 hours (.30 eh/ft^2 - .36 eh/ft^2). Installation time for a typical domestic hot water system was found to be approximately 64 hours (1.28 eh/ft^2), while for a space heating it was between 120-183 hours (.40 eh/ft^2 - .61 eh/ft^2).

From interviews with experienced solar consultants the Navarro research team concluded that the installation time for a typical domestic hot water system is approximately 1.0 eh/ft^2 of collector in retrofit construction. For space heating and hot water combined, that time is approximately .32 eh/ft^2 of collector. For new construction installations these times were expected to be reduced by approximately one half.

On average, the Navarro study calculated that a typical installation time for a domestic hot water system is .8 eh/ft^2, plus .2 eh/ft^2 for design and .04 eh/ft^2-/year for maintenance. The typical domestic space heating system requires .416 eh/ft^2 to install, .10 eh/ft^2 to design and .034 eh/ft^2/ year to maintain.

Table I summarizes the result of these studies.

TABLE I
INSTALLATION TIMES FOR SOLAR SYSTEMS

SYSTEM	EDD	CPPC	STUDY JPL	NAVARRO
Domestic Hot Water (New)	.36	.429	.417	.80 - 1.0
Domestic Hot Water (Retrofit)	.61	.858	.834	1.0 - 1.28
Space Heating (New)	-	-	.11	.40 - .61
Space Heating (Retrofit)	-	-	.75	.32 - .416
Hot Water & Space Heating (New)	-	.32	-	-
Hot Water & Space Heating (Refrofit)	-	.453	-	-

The numbers shown in Table I represent the employee hourst required for each square foot of collector area installed.

An analysis of the tasks for design, installation and maintenance for a typical solar system reveals that solar tasks account for approximately 20 percent of the total task time. The remaining 80 percent can be performed by solar-trained conventional tradespeople. HVAC journeyman skills are needed 5-6 percent of the time, nearly entirely during the design of the system for calculating space heating and cooling loads. Plumbing skills for a liquid system are required approximately 55 percent of the time. This same percentage applies to sheet metal skills for air systems.

Electrical skills are required about 4-5 percent of the time, carpentry about 1% and other skills (i.e., general laborer, insulation applicators, etc.) are required about 10% of the time.[4]

CONCLUSIONS

A substantial demand for trained skilled workers to design, install, and maintain solar systems will develop concurrently with the demand for solar equipment. According to the three national market projections used, there will be at least 2.4 million solar units installed by 1985. Accordingly, by that year there must be a minimum of 25,000 skilled workers in the solar field. One fifth of these workers must be trained at the technician level.

Regional feasibility of solar systems will determine regional manpower demand. As yet no extensive analysis of the employment demand created by increased solar utilization have been conducted for Washington State. This stems primarily from the lack of available (or accepted) estimates of market penetration of solar systems. Existing national and regional estimates indicate little or no demand for individuals trained to install and maintain solar systems. However, these estimates have been seriously questioned by many of the region's solar consultants.

1 - Schulze, William D. and Shaul Ben - David. "The Economics of Solar Home Heating" University of New Mexico, July 1976.

2 MITRE Corporation. "An Economic Analysis of Solar Water and Space Heating: The MITRE Corporation, July 1977.

3 Butt, Sheldon. "Solar Market Capture and Market Penetration." Solar Energy Industries Association, October 1976.

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5 Pacific Northwest Utilities Conference Committee. "Econometric Model-Electric Sales Forecast" February 1978. Pages B-43 and B-45.

6 Northwest Energy Policy Project. Energy Futures Northwest (Final Report). Pacific Northwest Regional Commission: Vancouver, WA.,1978.

7 Orsak, Charles G. et al. "An Assessment of Need for Developing and Implementing Technical and Skilled Worker Training for the Solar Energy Industry." Navarro College: Corsicana, Texas, October 1977.

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10 Petersen, H. Craig. "Sector-Specific Output and Employment Impacts of a Solar Space and Water Heating Industry." National Science Foundation, Research Applied to National Needs (RANN), December 1977.

11 California Employment Development Department. "A Comparative Analysis of the Employment Effects of Solar Energy in California" (DRAFT) State of California Health and Welfare Agency, Employment Development Department, October 1977.

12 Jet Propulsion Laboratory. "Solar Energy in Buildings: Implications for California Energy Policy." Jet Propulsion Laboratory, California Institute of Technology: Pasadena, California (1977)

13 Several other studies also indicate the greater labor intensity of solar systems vis-a-vis electric generating facilities. See Council on Economic Priorities (CEP). "Long Island Solar and Jobs Study" (CED, July 1978) and Skip Laitner "The Impact of Solar and Conservation Technologies Upon Labor Demand." Public Citizen/Congress Watch, May 1976.

14 Branfman, Fred. "Jobs from the Sun - Employment Development in the California Solar Energy Industry." California Public Policy Center, February 1978.

15 See for example U. S. Department of Energy Solar Energy for Pacific Northwest Residential Heating U. S. DOE Region X, May 1978; Ecotope Group "Solar Energy in the Northwest"; Northwest Energy Policy Project, Energy Supply and Environmental Impacts - Unconventional Sources." Pacific Northwest Regional Commission, 1978.

16 Danes, E. S. et al "Industrial Implications of Proposed California State Solar Energy Goal," April 1, 1977; April 19, 1977 Rev. 1; December 14, 1977 Rev. 2. Jet Propulsion Laboratory, California Institute of Technology; Pasadena, California.

17 Unless otherwise specifically identified the remainder of this section was developed from the results of work done by William D. Hunt in "Solar Technicians and Mechanics: A Preliminary Occupational Task Analysis" California State University; Chico and Charles Orsak, et al in "An Assessment of Need for Developing and Implementing Technical and Skilled Worker Training for the Solar-Industry." Navarro College, Corsicana, Texas. October 1977.

Seattle/Opportunities Industrialization Center

SOLAR SYSTEM MARKET PENETRATIONS FOR SEATTLE AND KING COUNTY, 1980-1986

prepared by Ecotope Group

Baseline Assumption and Condition:

1. Heating: Electric heat in King County is far more common than in Seattle. The saturation in the county is 50% while in the city is 35%. The saturation of gas heat is 40% in the city and 33% in the county. The remaining customers are heated by oil heat. Table I illustrates this condition.

2. Water Heating: The saturation of electric water heating is 89% in the county and 90% in the city. The remaining customers use gas for water heat. See Table I, below.

Table I

Customer Units and Different Energy Uses

	King County	Seattle
TOTAL	214,999	205,000
HEATING-Electric	107,000	71,000
-Gas	71,000	83,000
-Oil	36,000	51,000
WATER HEATING-Elec.	191,000	184,000
-Gas	23,000	21,000

3. Population Growth Rate: The growth assumed for King County is 6%/year. This area accounts for most of the growth in the region. The population growth rate in the City of Seattle is.5% per year.

4. Fuel Cost Escalation: The escalation in fuel cost is given in Table II. This assumes that Puget Sound Power and Light embarks on its program of thermal generation, and, as a result, experiences price escalation similar to private utilities in Oregon which followed a similar path.

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Table II

Competitive Fuel Prices ($/MMBTU)

	1978		1980		1981		1984		1986	
	King Co.	Seattle	King Co.	Seattle	King Co.	Seattle	King Co.	Seattle	King Co.	Seattle
Electric	$ 5.00	$ 4.40	$ 5.80	$ 4.60	$ 7.00	$ 4.80	$7.50	$5.00	$ 8.20	$ 5.40
Gas	4.90	4.90	5.20	5.20	5.50	5.50	5.80	5.80	6.20	6.20
Oil	5.00	5.00	5.40	5.40	5.70	5.70	6.10	6.10	6.40	6.40

5. Fuel Use Mix (Space Heating): The new construction will continue to be 95% electrically heated until the price disparity between gas and electricity exceeds 25%, then the shift to gas, oil and wood will begin. This condition will exist in King County after 1982, and as a result, the use of electric heat will decline and be replaced by burning oil, gas and wood or direct solar technologies. In the city, electricity will continued to be used for all new construction throughout the period.

6. Fuel Use Mix (Water Heating): For water heating a condition similar to space heating exists. After 1982, as electricity becomes increasingly expensive, the use of gas for water heating will become more common in the county. Seattle consumers will continue to choose electric hot water heating systems since they will remain the cheapest option.

Market Penetration Projection: Payback Methodology

This projection is based on the assumption that certain economic conditions must exist before solar energy systems are selected for installation in new construction and retrofit onto existing dwellings. The "payback period" is used to determine when these conditions exist. It is calculated by comparing the present annual cost of using a conventional space or water heating system with that of employing a solar technology to accomplish the same end use. To illustrate, if the present annual cost of heating a home with electricity would exceed the cost of heating it with solar in the sixth year of operation then the solar system's "payback period" would be six years.

It is further assumed for purposes of this projection that future fuel cost escalations beyond the general rate of inflation are ignored by the consumer. Therefore, if the price of conventional heating "fuels" (oil, gas, electricity) increases faster than inflation a consumer will underestimate the economic benefits of using a solar technology. The result of this assumption is a more conservative estimate of the demand for solar energy systems.

A third fundamental assumption made for purposes of this projection was that when payback periods for a particular solar technology reach certain points, a fixed percentage of all consumers will opt for solar systems. For example, if 15,000 people are building new homes in a particular year and the payback period for a passive solar space heating system is less than five years, then it was assumed that 40% of those consumers would select solar systems instead of a conventional heating system. These "saturation" assumptions are shown in Section III on the following page.

A detailed description of the assumptions used to develop this report's three scenarios for solar system market penetration in the Seattle and King County area are provided on pages 1,2,3 and 4 . Tables III and IV on pages 5 and 6 show the market penetration estimates computed from these assumptions through the year 1986.

I. Payback Period Assumptions:

A. Scenario 1 (baseline)
1. Discount Rate - 10%/year
2. Inflation Rate - 6%/year
3. Fuel Cost escalation rate-none
4. National Energy Act Tax Credits (30% on first $2,000, and 20% on next $8,000, up to $2,200 maximum credit

B. Scenario 2
1. Discount Rate - Same as baseline
2. Inflation Rate - Same as baseline
3. Fuel cost escalation Rate - Same as baseline
4. Nation Energy Act Tax Credits
5. Interest "free" loans available from utilities or government agencies

C. Scenario 3
1. Discount Rate - Same as basline
2. Inflation Rate - Same as baseline
3. Fuel Cost Escalation Rate - Same as baseline
4. Nation Energy Act Tax Credits
5. Interest "free" loans available from utilities or government agencies
6. 15% reduction in solar system cost

II. Solar Assumptions

A. Domestic Hot Water (Baseline)
1. System cost: $1,200 (60ft^2 of collector area @ $20/ft^2)
2. System output: 12.5 MMBTU/year of heated water
3. Maximum number of systems installed when payback criteria is not met: 100 units/year
4. Maximum number of systems installed when units/year in retrofit construction and 75% of all hot water systems installed in new construction.

B. Active System (Baseline)
1. System cost: $6,250 (250 ft^2 of collector @ $25/ft^2)
2. Active air system with diurnal storage
3. System output: 30 MMBTU of usable heat in an insulated house
4. Maximum number of systems installed when payback criteria is not met: 100
5. Maximum number of systems installed when payback period is met
   a. Retrofit maximum - 2,500 units/year in Seattle and 2,500 units/year in county
   b. New construction - 75% of all new dwellings

C. Passive Direct Gain (Trombe Wall)
1. System cost: $1,000 (250 ft^2 @ $4/ft^2)
2. System output: 20 MMBTU/of usable heat in an insulated house
3. Maximum number of systems installed when payback criteria is not met: 100
4. Maximum number of systems installed when payback criteria is met: 75% of all new dwellings

D. Passive Hybrid* (Attached greenhouse with rock bin and fan distribution)

1. System cost: $3,000 (250 ft^2@ $12/$ft^2$)
2. System output: 25 MMBTU/year, plus $100/year for food or other "non economic" benefits (e. g. living space)

III. Saturation Criteria:

A. Domestic Hot Water
1. Payback period (excluding fuel cost escalator) must fall below 10 years to achieve 25% maximum saturation and under 6 years to achieve maximum saturation.

B. Space Heating Systems:
1. Payback period less than 15 years
   a. 5% maximum saturation in new construction
   b. 5% maximum saturation in retrofits
2. Payback period less than 10 years
   a. 25% maximum saturation in new construction and retrofits
3. Payback period less than 5 years
   a. 40% maximum saturation in new construction and retrofits

*Passive hybrid systems are considered a close competitor to Passive Director Gain, therefore they have been assumed to share the same market, rather than develop independent markets.

TABLE III

SEATTLE

					Solar Scenario 1			Solar Scenario 2			Solar Scenario 3		
	Electric	Other	Electric	Gas	Active	Passive	Water Heating	Active	Passive	Water Heating	Active	Passive	Water Heating
1978	71,000	135,000	84,000	21,000									
cost/ MBTU	4.40	5.00	4.40	5.00									
1980	76,000	131,000	185,000	21,000		200			1400	400		1400	400
cost/ MBTU	4.60	5.30	4.60	5.30									
1982	82,000	126,000	187,000	21,000	100	400	100	100	3100	800	100	3100	800
cost/ MBTU	4.80	5.50	4.80	5.50									
1984	88,000	126,000	189,000	21,000	100	600	200	100	4800	1200	100	4800	1200
cost/ MBTU	5.00	5.90	5.00	5.90									
1986	94,000	122,000	191,000	21,000	200	800	300	200	6300	1600	200	6300	1600
cost/ MBTU	5.40	6.30	5.40	6.30									

Note: All columns are cumulative.

TABLE IV

KING COUNTY

	Heating Customers		Water Heating		Solar #1			Solar #2			Solar #3		
	Electric	Other	Electric	Gas	Active	Passive	Water Heating	Active	Passive	Water Heating	Active	Passive	Water Heatin
1978	107,000	107,000	191,000	23,000									
cost/ MBTU	5.00	5.00	5.00	5.00									
1980	122,000	118,000	215,000	25,000	100	900	100	100	5200	500	100	5200	1000
cost/ MBTU	5.80	5.30	5.80	5.30									
1982	120,000	149,000	229,000	40,000	100	2900	200	100	11,000	1000	300	11,000	4000
cost/ MBTU	7.00	5.60	7.00	5.60									
1984	118,000	184,000	246,000	56,000	200	4900	700	200	17,200	1500	700	17,200	7000
cost/ MBTU	7.50	5.90	7.50	5.90									
1986	113,000	220,000	262,000	71,000	200	6900	1200	200	21,500	4500	1200	21,500	22,000
cost/ MBTU	8.20	5.40	8.20	5.40									

Note: All columns are cumulative.

Seattle/Opportunities Industrialization Center

AN OCCUPATIONAL TASK ANALYSIS FOR SOLAR MECHANICS

Introduction

Vocational curriculum development should attempt to match course content and objectives with specific tasks, activities and operations inherent in the vocation. For solar occupations it must also be consistent with the specific solar technology(s) involved. And, because solar energy technology is interrelated with existing skills and vocational curriculum in electronics, electricity, conventional heating and air conditioning, plumbing and building construction technology, solar vocational instruction must mesh with existing training programs.

The performance of an occupational task analysis for solar vocations, therefore, requires that three decisions be made. The curriculum developer must decide:

1. Which solar technology is most appropriate (i.e. will likely achieve the greatest use) for the area in which most graduates of the training program will find employment.

2. Whether the training program will attempt to produce "entry level" or "advanced" graduates; and,

3. Whether the curriculum will augment an existing curriculum in related vocations, e.g. carpentry, or be offered as an independent course.

Research and discussions conducted during earlier phases of this project provide the basis for making these decisions. As discussed in previous working papers, the solar technologies which appear to be most appropriate to the climate and economics of Western Washington in the near term are passive and passive/hybrid space heating, and domestic hot water heating systems. Active air space heating systems, while not anticipated to experience as wide a use as the "passive" systems, were also included because such systems are currently experiencing the greatest use of any "active system." Therefore, this project's occupational task analysis will concentrate on the skills and knowledge needed to install and maintain solar equipment common to the most appropriate technologies for this region.

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Educators preparing curriculum for vocational programs are faced with the perplexing dilemma of whether to prepare students for highly skilled employment in a specific occupation or to provide broad programs of general training for a wide variety of occupations at the "entry level." A survey of and discussions with several solar industry members and Seattle/OIC's Solar Energy Technical Advisory Committee indicated that all of the tasks needed to design, size, install and maintain solar equipment would most likely not be performed by one individual or role within the normal business environment. The consensus of opinion appears to be that at least two distinct occupations will evolve: (1) a person who performs primarily mechanical tasks, and (2) a person who performs primarily quantitative tasks, some supervisory tasks, and some mechanical tasks. The first category is most commonly referred to as a "Solar Mechanic", and the second category as "Solar Technician." Traditionally, Seattle/OIC has concentrated its programs on the preparation of its students for "entry level" employment. Consistent with this tradition the decision has been made to focus the organization's initial solar training programs on "entry level" skills and knowledge. Therefore, this task analysis will concentrate on the first occupational category noted above--the Solar Mechanic.

As originally proposed, the curriculum developed under this project would be used to augment training in existing vocational areas. No information has been developed during the course of this project which challenges the legitimacy of this approach. Indeed, this appears to be the most appropriate approach at this time. Therefore, this task analysis will concentrate on the identification of those tasks which are distinct from those already performed by entry level carpentry, plumbing and pipefitting and electrical maintenance graduates. It should be noted, however, that three other skill areas--sheet metal, glaziers, and masons--were also included in this analysis for potential later curricular expansion.

Task Analysis

This task analysis has been divided into five sections. Each section lists the task which must be performed during the installation and routine maintenance of one of the technologies identified as having the greatest potential for widespread use in the near term. Each of these task has also been assigned to an existing trade area.

It should be noted that the task identified were judged appropriate for performance by an "entry level" solar worker. They are limited to those task involved in solar system installation and do not include either design, sizing or diagnostic maintenance.

I. Domestic Hot Water (Thermosyphon)

A. Plumbing

- Modify existing domestic hot water system to accept solar apparatus in accordance with relevant plumbing codes.
- Install solar system in series with existing domestic hot water system in accordance with relevant plumbing codes.
- Modify and/or relocate existing plumbing and exhaust vents on roof.
- Install heat exchanger freeze protection systems which employ antifreeze solutions.
- Insulate pipes and hot water storage tank.
- Check condition of existing energy conservation measures, e.g. thermostat setting, pipe insulation, related to hot water system.
- Fill and test system for leaks.
- Drain, flush & refill & properly dispose of spent antifreeze.
- Perform routine maintenance and repair of pipe, tank and collector.

B. Carpentry

- Locate collection areas with respect to orientation, tilt and shading.
- Build wooden frames (boxes) for collector plates.
- Cut and install glass or plastic glazing on collectors.
- Install solar collectors on existing roof or at ground level.
- Modify roof structural members to support storage tank.
- Construct and install hot water storage tank on roof or in attic.
- Cut holes in existing roof for pipe.
- Flash, seal and caulk around pipe.
- Modify or repair plasterboard and interior/exterior walls.

C. Electrical

- Install and test electrical resistance heat tape for freeze protection.

II. Domestic Hot Water System (Active)

A. Plumbing

Same as for thermosyphon system with the addition of:

- Install and test circulating pumps.
- Perform routine maintenance and repair of circulating pumps.
- Install fireplace/wood stove heating coils or heat exchanger.

B. Carpentry

Same as for thermosyphon

C. Electrical

- Install and test heat sensors.
- Wire and test differential controls.
- Perform routine maintenance and repair of electrical controls.

III. Solar Heating (Active Air)

A. Sheet Metal

- Fabricate metal or aluminum frames (boxes) for collectors.
- Install and seal air handlers and in-duct dampers and check for air leakage.
- Check damper seals for air leakage.
- Install duct insulation.
- Install supply registers and return ducts and check for leaks.
- Modify existing air handling units to accept solar apparatus and check for leaks.

B. Carpentry

- Locate collection areas with respect to orientation, tilt and shading.
- Build wooden frames (boxes) for collector plates.
- Cut and install glass or plastic glazing in collector.
- Install solar collectors on existing roof or at ground level.
- Cut holes in existing roof for air ducts.
- Flash, seal and caulk around air ducts.
- Modify or repair plasterboard and interior/exterior walls.

C. Electrical, continued

- Install and test thermal sensors.
- Install and test differential controls.
- Perform routine maintenance of fans and controls.

V. Solar Passive/Hybrid Greenhouse

A. Carpentry

Same as for Passive Solar/Direct Gain (Trombe) with the addition of:

- Construct form work for greenhouse foundation.
- Modify existing interior/exterior greenhouse walls to accept greenhouse.
  - Frame greenhouse.
  - Construct glazing detail for greenhouse.
  - Install glazing and weatherseals around greenhouse/side wall interface.
  - Install greenhouse glass and/or plastic glazing.
  - Build and install rock bin storage subsystem.
  - Build, install, seal and test for air leaks plywood ducts.
  - Mount squirrel cage fans.
  - Repair and replace broken seals and glazing.
  - Perform routine maintenance and repair of framing.

B. Electrical

- Install and test thermal sensors.
- Install and test control equipment.
- Install and test motorized fans and dampers.
- Perform routine maintenance and repair of solar controls, blowers and fans.

APPENDIX X

Seattle/Opportunities Industrialization Center

SOLAR MECHANICS VOCATIONAL CURRICULUM

PRELIMINARY COURSE DESCRIPTION, GOALS, OBJECTIVES AND COURSE CONTENT OUTLINE

Introduction

This paper outlines the preliminary course description, goals, and learning objectives for a "Solar Mechanics" vocational curriculum. The purpose of this curriculum is to provide skills training related to the performance of solar space and water heating system installation and routine maintenance. It is assumed that individuals entering this program already possess "entry level" skills in one of the following trades: carpentry, plumbing and pipefitting or electrical maintenance. As a result, only the knowlege and skills which are uniquely "solar" are included.

Course Description

I. Scope

The total course duration is 6 to 8 weeks. The course is divided into the following blocks:

A. Introduction to Energy Conservation and Solar Energy
B. Basic Solar Domestic Water Heating Installation & Servicing
C. Basic Solar Space Heating Installation & Servicing

II. Methodology

The Solar Mechanics program is conducted on an open entry/open exit basis. All learning is individualized. The course content is approximately evenly divided between theoretical and practical training. Theory includes blueprint reading, mathematics, and solar terminology and materials. Practical training includes hands-on construction and installation of various solar system components.

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III. Course Goal

The Solar Mechanics program is designed to provide carpentry, electrical maintenance and plumbing and pipefitting trainees with the basic knowledge and skills needed to install and perform routine maintenance on solar space and water heating systems.

IV. Prime Objectives

Upon completion of the course, the trainee should be able to:

1. Identify, understand and perform measures which improve the thermal energy efficiency of typical residential and/or light commercial structures.
2. Identify and understand the function of all the components in passive, passive-hybrid and active air space and both passive (thermosyphon) and active domestic water heating systems.
3. Assemble, start up and test both active and passive solar space and water heating systems following written and verbal instructions.
4. Assist in troubleshooting common solar heating operational problems.
5. Perform routine maintenance according to manufacturers warranty requirements.
6. Assist in planning and supervising the installation of solar components in residences and other lightly constructed buildings with no unusual occupancy requirements.

V. General Course Objectives

Upon completion of their solar-related intruction trainees will be able to:

1. Give examples of how heat is lost or gained through conduction, radiation and convection.
2. Identify the routes and mechanisms by which heat is lost/gained in a typical residential or light commercial structure (e.g. through infiltration around doors and windows).
3. Calculate heat loss/gain in terminal residential buildings.
4. Identify and perform corrective measures to reduce heat loss in a typical residential and/or ligh commercial structure.
5. Explain how local and site specific climatic conditions affect solar technology selection and system design.
6. Explain why the intensity of solar radiation is affected by the time of day and season of the year.

7. Explain the principal differences between passive, passive-hybrid and active solar technologies.

8. Recognize and explain the function of the major components of solar space and water heating systems.

9. Distinguish the differences between air and liquid systems.

10. Describe the types of systems which have practical value as opposed to systems under development with future promise.

11. Describe the basic expectation of performance of different types of solar technologies.

12. Recognize and describe the advantages and disadvantages of the various components within solar space and domestic hot water heating systems.

13. Name the climatological characteristics which influence the sizing of a solar space or water heating system.

14. Identify the items involved in the costing of a solar space or water heating system.

15. Explain how the availability and cost of conventional fuels will impact the use and economics of solar space and water heating systems.

16. Recognize those conditions--for example, clouds, dust and other atmospheric pollutants; shading trees and buildings; collector orientation and tilt--which affect solar energy reaching the collector.

17. Describe the differences between direct and diffuse radiation.

18. Recognize the various units of measure used to report solar radiation.

19. Convert solar radiation from one unit of measurement to another using standard conversion factors.

20. Determine the amount of solar radiation available for a given period of time.

21. Learn and locate sources of information on solar technologies.

22. Explain the differences between flat plate and concentrating collectors.

23. Identify the design differences between air and liquid collectors.

24. Describe the operating principles of various components in the collector.

25. Recognize different absorber plate designs and method of manufacture.

26. Identify the materials are used for heat transfer mediums and list their advantages and disadvantages.

27. Explain the concepts of sizing a heat storage unit.

28. Solve problems of sizing a heat storage units.

29. Discuss where storage units can be placed.

30. List the factors that affect the advantages and disadvantages of different kinds of heat storage units.

31. Identify advantages and disadvantages of various heat storage practices.

32. Describe the materials used in the manufacture and in the installation practices for heat storage units.

33. Perform the installation of heat storage units when given blueprints and/or schematics.

34. Discuss the operating principles of a centrifugal circulating pump.

35. Discuss the operating principles of an air circulating blower.

36. Describe how a heat exchanger functions.

37. Identify various types of heat exchangers and explain their advantages and disadvantages.

38. Identify the various electrical control devices used in solar space and water heating systems and explain their function.

39. Explain the functions of various hydronic specialty items used in the control of air or liquid solar space heating systems.

40. Identify the major components of a typical passive solar heating system and explain their function.

41. Identify the major components in a typical passive-hybrid solar heating system and explain their function.

42. Describe the basic operating modes of an active air solar heating system.

43. Determine which components of active air space heating systems should be operating and which valves or dampers should be open during each operating mode.

44. Describe the importance of eliminating air leaks in all active air and passive-hybrid solar heating systems.

45. Identify the safety devices required on the domestic hot water sub-system.

46. Identify the basic differences between air and hydronic solar space heating systems.

47. Describe three different ways heat pumps can be coupled to solar heating systems.

48. Describe the basic types of solar domestic water heating systems and identify the basic components of each.

49. Explain the advantages and disadvantages of air versus liquid domestic water heating systems.

50. Describe the operating cycles of the three basic systems for heating domestic hot water.

51. Explain architectural problems related to installing solar heating systems.

52. Schedule and install collector arrays.

53. Schedule and install heat storage units.

54. Schedule and install controls and speciality items.

55. Schedule and install domestic hot water systems.

56. Schedule and install insulation, vapor barrier, vents and weatherstripping and caulking.

57. Discuss the general information necessary for start-up of active solar space and domestic hot water systems.

58. Perform the operations necessary to start up of a domestic hot water system.

59. Perform the operations necessary for the start-up of passive-hybrid solar space heating system.

60. Identify and perform the periodic maintenance procedures for various components of the solar heating system.

61. Explain and perform troubleshooting procedures for a system that needs emergency servicing.

62. Discuss and solve maintenance problems that are common among solar heating and domestic water systems.

63. Describe the purpose and extent of warranties.

64. Describe the hazards of solar heating system harmful to people and property.

65. Discuss building codes and zoning requirements as they relate to various types of solar systems.

TENTATIVE SOLAR MECHANICS COURSE CONTENT OUTLINE

I. Introduction to Energy

- A. World Situation
- B. Renewable and Non-renewables
- C. Energy quantity and quality (i.e., thermodynamics)

II. Introduction to Solar

- A. History and Use
  - 1. Passive Systems
  - 2. Active Systems
- B. Matching Systems to End-Use
- C. Matching Systems to Climate

III. Solar in the Pacific Northwest

- A. Limiting Factors
- B. Appropriate Systems
  - 1. Passive
  - 2. Active
- C. Energy Conservation

IV. Site Assessment

- A. Exposure
- B. Latitude
- C. Solar Arpetiture (Use of Sun Path Chart)
- D. Placement & Serving
- E. Micro-climate

V. System Design

- A. Energy Conservation
- B. Heat Loss
- C. Heat Gain
- D. Sizing
  - 1. Collector
  - 2. Storage
  - 3. Back-up Systems
  - 4. Heat Exchangers
- E. Design Options

VI. Materials

- A. Performance
- B. Availability
- C. Cost
- D. Durability

VII. Hydronic vs. Air Systems

A. Performance/Economics
B. Cost
C. Maintenance
D. Availability

VIII. Installation Considerations

A. Retrofit/Remodel
   1. Tie-in with existing systems
      a. air
      b. water
   2. Hardware
   3. Thermal performance
   4. Codes

B. New Construction
   1. Passive designs
   2. Active designs
   3. Economics
   4. Codes

IX. Maintenance

A. Routine Procedures
B. Trouble Shooting Common Problems
   1. Glazing & Seals
   2. Controls & Fans
   3. Pumps

X. Solar as a Business

A. Market & Marketing
B. Customer Education
C. Warranties
D. Timing

APPENDIX IX

Seattle/Opportunities Industrialization Center

MANPOWER PROJECTIONS FOR SOLAR INSTALLATIONS, SEATTLE AND KING COUNTY 1980-1986

Introduction

The attached tables project the direct labor requirements needed to install solar systems based on three levels of market penetration. The baseline case (Scenario #1) assumes that no additional incentives beyond those contained in the National Energy Act will be provided to promote solar energy utilization. Scenario #2 assumes that, in addition to the tax credits in the National Energy Act, "no interest" loans will be made available through either utility or government programs for the purchase of solar systems. The final estimate, Scenario #3 adds to the tax credits and no interest loan programs a 15% cost reduction in solar systems brought about by technology improvements or mass production. A complete description of the derivation of these scenarios and the actual number of solar systems forecast to be installed under each set of assumptions appears in Working Paper IV, "Solar System Market Penetrations for Seattle and King County, 1980 - 1986" prepared by Ecotope Group for Seattle/OIC.

EXPLANATION OF METHODOLOGY AND ASSUMPTIONS

The conceptual formula used in this project used for calculating manpower requirements is as follows:

$$\text{Yearly Manpower} = \frac{(I_a \times T_a) + (I_p \times T_p) + (I_h \times T_h)}{2080} + \frac{(I_{ar} \times T_{ar}) + (I_{pr} \times T_{pr}) + (I_{hr} + T_{hr})}{2080}$$

Where:

I_a = Number of active space heating systems installed per year in new construction.

T_a = Time required to install active space heating systems in new construction.

I_p = Number of passive and passive hybrid systems installed per year in new construction.

T_p = Time required to install passive and passive hybrid systems in new construction.

I_h = Number of domestic solar hot water heating systems installed per year in new construction.

T_h = Time required to install domestic solar hot water heating systems in new construction.

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I_{ar} = Number of active space heating systems retrofit into existing dwellings each year.

T_{ar} = Time required to install (retrofit) active space heating systems on existing dwellings.

I_{pr} = Number of passive and passive hybrid space heating systems retrofit onto existing dwellings each year.

T_{pr} = Time required to install (retrofit) passive and passive hybrid space heating systems onto existing dwellings.

I_{hr} = Number of domestic solar hot water heating systems retrofit onto existing dwellings.

2080 = The number of hours worked by the average employee each year. Also equivalent to one (1) employee year (EY).

For purposes of this project the following installation times were assumed:

Active Space Heating in new construction (T_a) = .4 employee hours(ehrs) per ft^2 of collector

Active Space Heating in retrofit construction (T_{ar}) = .61 ehrs/ft^2 of collector

Passive and Passive Hybrid in new construction (Tp) = .4 ehrs/ft^2 of glazed surface for passive and .6 ehrs/ft^2 of glazed surface for passive hybrid adjusted to an average of .5 ehrs/ft^2 based on an assumed 50/50 ratio of passive/passive hybrid installations.

Passive and Passive Hybrid in retrofit construction (T_{pr}) = .6 ehrs/ft^2 of glazed surface for passive and .75 ehrs/ft^2 of glazed surface for passive hybrid, adjusted to an average of .68 ehrs/ft^2 based on an assumed 50/50 ratio of passive/passive hybrid installations.

Domestic solar hot water heating in new construction (T_h) = .36 ehrs/ft^2 of collector area

Domestic solar hot water heating in retrofit construction (T_{hr}) = 1.0 ehrs/ft^2 of collector area

The above values were derived from the results of a review of the literature as reported in Working Paper #I, "An Assessment of the Need for Developing and Implementing Vocational Training for the Solar Energy Industry in Washington State - A Litereature Review."

RESULTS

Using the above formula and values, the labor requirements for each of three solar technologies were calculated. Table I shows the range of the manpower requirements for two-year increments between 1980 and 1986 in employee years. The number represent only the cumulative direct employment needs in solar system installation. They do not account for either the manpower requirements of design, fabrication and maintenance or the indirect employment created as a result of the solar activity. The range given represents an upper and lower limit of the labor requirements resulting from the installation of the number

of solar systems forecast by Ecotope Group in Working Paper IV to be installed in each of the biennial periods shown.

Table II indicates the average biennial net growth in labor requirements created by the installation of solar systems in Seattle and King County under the three scenarios for growth assumed in Working Paper IV. Table II also shows the total mid-range estimate of demand for labor to install solar systems between 1980 and 1986.

It should be noted that the estimates given in both Table I and Table II represent gross demand. Subsequently, one must assume that the net demand (net demand= gross demand - supply) for solar system installers will be less by some unknown (and presently incalculable) amount.

TABLE I

MANPOWER PROJECTIONS FOR SOLAR INSTALLATIONS
SEATTLE AND KING COUNTY

Range of Employee Years* Required by Type of Technology
Cumulative Growth 1980-1986

	SOLAR SCENARIO #1			SOLAR SCENARIO #2			SOLAR SCENARIO #3		
YEAR	ACTIVE	PASSIVE	H_2O HEATING	ACTIVE	PASSIVE	H_2O HEATING	ACTIVE	PASSIVE	H_2O HEATING
Seattle									
1980	----	12 -16	---	----	84-114	4-11	---	84-114	4-11
1982	5-7	24-32	1-3	5-7	186-251	8-23	5-7	186-251	8-23
1984	5-7	36-49	2-6	5-7	288-390	12-35	5-7	288-390	12-35
1986	10-15	48-65	3-9	10-15	378-511	17-46	10-15	378-511	17-46
King Co.									
1980	5-7	54-73	1-3	5-7	312-422	5-14	1-3	312-422	10-29
1982	5-7	174-236	2-6	5-7	661-894	10-29	14-22	661-894	42-115
1984	10-15	294-398	7-20	10-15	1034-1398	16-43	34-51	1034-1398	73-202
1986	10-15	414-560	12-34	10-15	1292-1747	47-130	58-88	1292-1747	228-635

* 1 Employee Year = 2080 Employee Hours

TABLE II

MANPOWER PROJECTIONS FOR SOLAR INSTALLATIONS
SEATTLE AND KING COUNTY

MID-RANGE ESTIMATE OF BIENNUAL NET GROWTH IN
LABOR REQUIREMENTS (Number of Employee Years) by Type of Technology
1980 - 1986

	SOLAR SCENARIO #1			SOLAR SCENARIO #2			SOLAR SCENARIO #3		
YEAR	ACTIVE	PASSIVE	H_2O HEATING	ACTIVE	PASSIVE	H_2O HEATING	ACTIVE	PASSIVE	H_2O HEATING
Seattle									
1980	---	14	---	----	99	8	---	99	8
1982	6	14	2	6	120	11	6	120	11
1984	1	15	3	1	121	14	1	121	14
1986	6	15	5	6	112	17	6	112	17
TOTAL 1980-86	13	58	10	13	452	50	13	452	50
King Co.									
1980	6	64	2	6	367	10	2	367	20
1982	1	142	3	1	400	14	16	400	59
1984	7	141	10	7	439	17	25	439	80
1986	3	141	14	3	356	59	31	356	294
TOTAL 1980-86	17	488	29	17	1562	100	90	1562	453
GRAND TOTAL	30	546	39	30	2014	150	103	2014	503